

CREATIVITY AND SOCIAL NETWORKS:  
THE RELATIONAL ADVANTAGE OF STRONG TIES

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CREATIVITY AND SOCIAL NETWORKS:  
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Social networks research focusing on the link between tie strength and creativity has concluded that weak ties are beneficial. The explanation offered is that weak ties provide access to a greater amount of non-redundant information. However, when ties can potentially provide access to non-redundant information, I argue that strong ties should facilitate combining non-redundant information to enhance creativity. In support, the present study links strong ties to individual and group creativity. At the individual level, since individuals are more likely to trust the competence of strong ties and be more comfortable openly discussing ideas with strong ties, individuals will think more creatively when combining non-redundant information received from strong ties to generate new ideas. Openly discussing ideas, in particular, has a greater impact on creative thinking when an individual interacts with another with the same functional expertise. This is because openly discussing ideas facilitates sharing and combining tacit knowledge to generate new ideas. At the group level, trust and cooperative norms mediate the link between group tie strength and group creative processing. Moreover, conflict moderates the link between group creative processing and group creative outcomes. Taken together, these results suggest the relationship between tie strength and creativity may be more complex than previously asserted. In discussing the implications of this work, I offer possible explanations and directions for new research.

## BIOGRAPHICAL SKETCH

Kevyn received undergraduate degrees in Psychology and Philosophy from the National University of Singapore in 2000. He also received a Masters in Education from Harvard University in 2001. Upon completing his masters, he joined the NUS business school at the National University of Singapore as a teaching fellow before enrolling in the Ph.D. program in Management and Organizations at the S.C. Johnson Graduate School of Management at Cornell University. He earned his Ph.D. in August of 2008.

*I dedicate this work to*

*Mom & Dad*

*Ju & Ken*

*Charlene & Cillian*

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## PREFACE

### CREATIVITY AND SOCIAL NETWORKS

Creativity is valued for the role it plays in generating the ideas and solutions that lead to process and product innovations (Amabile, 1988; Audia & Goncalo, 2007; Nonaka, 1994). Less obvious are the non-tangible benefits creativity can bring to organizations, such as experiencing flow (i.e. a mental state of being fully immersed in the process of an activity) when engaging in intrinsically motivating work (e.g. Mainemelis, 2001; Quinn, 2005), positive affect associated with a sense of achievement (e.g. Amabile, Barsade, Mueller, & Staw, 2005), and lower job turnover (e.g. Shalley, Gilson, & Blum, 2000). For these reasons, creativity has been a significant interest in organizational research in the past twenty years (e.g. Amabile, 1988; Drazin, Glynn, & Kazanjian, 1999; Goncalo & Staw, 2006; Hargadon & Bechky, 2006; Taylor & Greve, 2006; Woodman, Sawyer, & Griffin, 1993). Furthermore, recent reviews indicate that scholarly interest in creativity is growing and there is much to be discovered about creativity in organizations (George, 2007; Shalley, Zhou, & Oldham, 2004). One area in particular that is gaining more attention is the link between creativity and social networks.

Drawing on the definition of creativity as generating novel and useful ideas, solutions, or products (Amabile, 1998; Drazin et al., 1999; Oldham & Cummings, 1996; Woodman et al., 1993), research studying the link between creativity and social networks has revealed a structural effect of network ties (Burt, 2004; Cattani & Ferriani, 2008; Fleming & Marx, 2006; Fleming, Mingo, & Chen, 2007; Guimera, Uzzi, Spiro, & Amaral, 2005; Perry-Smith, 2006; Perry-Smith & Shalley, 2003; Uzzi & Spiro, 2005). Individuals whose network ties reflect weaker relationships (i.e. lower interaction frequency and less relationship closeness of a network tie), centrality (i.e.

relative importance of a network position), and structural holes (i.e. social gaps between groups in a network), have been found to be more creative than those who do not occupy such network positions (Burt, 2004; Cattani & Ferriani, 2008; Fleming, Mingo, & Chen, 2007; Perry-Smith, 2006; Perry-Smith & Shalley, 2003). These researchers interpret their findings based on the premise that network ties directly affect the amount of non-redundant information received by individuals and in turn, receiving greater amounts of non-redundant information positively affects creativity. Additionally, individual network ties have also been postulated to affect group creativity. Individual members' ties to each other have been suggested to collectively affect the exchange of non-redundant within the group (Uzzi & Spiro, 2005); whereas individual members' external ties collectively affect the amount of non-redundant information received by the group (Guimera et al., 2005; Joshi, 2006). Thus, social networks research to date has contributed to our understanding of creativity by suggesting that social network ties affects the amount of non-redundant information an individual or group can access from others.

However, accessing non-redundant information only facilitates creativity when individuals learn something new or gain new insights from the non-redundant information they access. When an individual has access to non-redundant information, it does not necessarily mean that the individual will recognize the usefulness or combine the non-redundant information with their own to generate new ideas or to solve a problem. Thus, while social network ties that provide access to non-redundant information certainly reflects a higher potential for facilitating creativity, current research can benefit from a deeper understanding of the psychological mechanisms that lead people to learn, gain new insights, and use non-redundant information received from network ties to generate creative ideas or solutions (Fleming et al., 2007). To this end, I draw on social networks research on information transfer

(Borgatti & Cross, 2003; Levin & Cross, 2004; Szulanski, 1996) and psychology research on information processing (Hargadon & Bechky, 2006; Heath & Gonzalez, 1999; Smith, 1999) to suggest that relational mechanisms such as trust and openness to new ideas (Levin & Cross, 2004; Mikulincer & Arad, 1999; Tjosvold & Deemer, 1986) might provide an explanation for the link between individual creative thinking and accessing non-redundant information from network ties. Furthermore, because group creativity depends on the collective effect of information exchange and discussion between group members, I also suggest that group-level relational mechanisms such as trust (Jehn & Mannix, 2001; Simons & Peterson, 2000), cooperative norms (Chatman & Flynn, 2001), psychological safety (Edmondson, 1999), and conflict (Jehn & Mannix, 2001) might provide an explanation for the link between group creativity and group members accessing non-redundant information from each other.

In this dissertation, I argue that individual and group creativity depends more on the perceived usefulness of non-redundant information than on the amount of non-redundant information available; and by *useful* I mean that information recipients expend effort thinking about the received information to learn something new, gain new insights, and to combine the received information with their own to generate new ideas. I begin my argument with the findings in social networks research that show effective information transfer and learning depends on the relational mechanisms linking network ties to information seeking behavior and the perceived receipt of useful information (Borgatti & Cross, 2003; Levin & Cross, 2004; Szulanski, 1996). For instance, trusting the information provider's expertise, skills and knowledge accounts for the link between tie strength and the perceived receipt of useful information (Levin & Cross, 2004). This suggests that non-redundancy by itself may

not be sufficient for information received from others to facilitate creativity. Instead, it appears that received non-redundant information need to be perceived as useful.

Perceived usefulness of non-redundant information, however, may not always influence thinking such that individuals will generate new ideas or solutions that are more novel and useful than their initial ideas. An individual's initial ideas can have a constraining effect on how useful non-redundant information, received from others, is processed (e.g. Smith, 1995, 2003). One common occurrence is that in explaining the underlying rationale of his/her initial ideas to others, individuals gain confidence in their initial ideas such that they might ignore, rationalize, or simply discard useful non-redundant information (Heath & Gonzalez, 1999). Even when useful non-redundant information is available through social interaction, this information may not always benefit creativity. Indeed, Hargadon and Bechky (2006) argue that social interaction facilitates creativity only when individuals mindfully processes the non-redundant information provided by the other person. Because mindfulness reflects the amount of effort and attention paid to processing information provided by others (Hargadon & Bechky, 2006), it is likely that how mindful an individual is during a particular interaction is likely to vary with the strength of that particular relationship between recipient and provider. For example, given that individuals perceive information received from trusted others to be more useful than information received from less trusted others (Levin & Cross, 2004), it may be that individuals will expend more effort and attention with non-redundant information provided by trusted others compared with non-redundant information provided by less trusted others. Since expending more effort and attention during social interaction has been found to facilitate creativity (Hargadon & Bechky, 2006), it may be that relational mechanisms such as trust might provide a finer grained explanation linking social network ties to creativity that goes beyond informational non-redundancy. Therefore, in this

dissertation, I propose and test a theory of the relational mechanisms linking social network ties to creativity.

In chapter one, I focus on individual creativity at the dyadic tie-level and individual-level of analysis. At the tie-level, I argue that an individual thinks more creatively when interacting with strong ties whom they have a more open and trusting relationship. Consequently, at the individual-level, the person with a greater number of strong ties should be more creative than the person who has fewer strong ties.

In chapter two, I focus on group-level creative processing and outcomes. I argue that strong dyadic tie relationships between group members collectively affect the development of group-level cooperative norms and trust that facilitate group creative processing. I further argue that group creative processing leads to group creative outcomes when low group-level conflict accompanies group creative processing. While group creative processing drives the novelty of a project, group-level conflict is negatively associated with getting group-level project work done effectively. Hence, I argue that group creative processing leads to group creative outcomes when accompanied by lower group-level conflict. Conversely, group creative processing accompanied by higher group-level conflict is likely to lead to less creative group outcomes because of the group's ineffectiveness at getting work done.

In chapter three, I present a field study of scientists in a nanobiotechnology research and development setting. I use a combination of survey and full-roster social network methods to collect relational, creative processing, and creative performance data at individual and group levels. Statistical analyses suggest that, at the tie-level of analysis, competence-based trust and open discussion of ideas mediates the relationship between tie strength and individual creative thinking. The link between open discussion of ideas and individual creative thinking is further moderated by informational redundancy such that open discussion of ideas has a greater positive

effect on individual creative thinking when an individual interacts with another who has expertise in the same functional discipline. Consequently, individuals who had a greater number of strong ties were found to be more creative as indicated by peer and supervisor ratings of individual creativity.

To test the hypotheses on group creative processing and outcomes, I constructed a density measure of group-level tie strength and group creative processing from bi-directional measures of the dyadic-level tie relationships and dyadic-level creative processing, respectively. In so doing, I show that cooperative norms and group-level trust, but not psychological safety, mediates the link between group-level tie strength and group creative processing. I further show that group-level conflict moderates the link between group creative processing and group creative outcomes. This moderating relationship suggests that group creative processing, when accompanied by lower group-conflict, leads to higher group creative outcomes. In contrast, when accompanied by higher group-conflict, group creative processing leads to lower group creative outcomes.

Finally, in chapter four, I review the theoretical and methodological implications of this study's findings. Theoretically, I suggest that in organizational contexts where work projects depend on inter-disciplinary work, strong network ties provide a relational advantage in facilitating creativity. Methodologically, I suggest that future research should combine social psychological methods designed to measure relational and cognitive mechanisms with network methods designed to measure network structure when studying the link between creativity and social networks.

## CHAPTER 1

### INDIVIDUAL CREATIVITY AND SOCIAL NETWORK TIES

Creativity is the process of generating novel and useful ideas, solutions, or products (Amabile, 1988; Drazin et al., 1999; George, 2007; Shalley et al, 2004; Woodman et al., 1993). For instance, when problem solving, the greater the number of possible solutions an individual can think of, the greater the likelihood the individual will combine these solutions to generate potentially creative solutions (Simonton, 1999). Individual creativity, therefore, consists of two aspects. Individual creativity first consists of the psychological mechanisms underlying an individual's thinking as he/she combines or re-configures information to think up new and useful ideas and solutions. The second aspect reflects an individual's productivity in producing creative work outcomes. While producing creative work outcomes necessarily depends on creative thinking, it is not certain that creative thinking will leads to the successful production of creative work outcomes (Drazin et al., 1999). This is because while an individual may have thought up new and useful ideas and solutions, the individual's ability to implement these ideas and solutions is subject to contextual factors beyond the individual's control, such as budget constraints and technology limitations. Thus, creative thinking and creative work productivity are distinct but interrelated constructs.

Consistent with this distinction, researchers studying the link between individual creativity and social networks theorize that creative work productivity depends on exposure to non-redundant information (e.g. Burt, 2004; Fleming et al., 2007; McFadyen & Cannella, 2004; Obstfeld, 2005; Perry-Smith, 2006; Perry-Smith & Shalley, 2003). These researchers assert that the amount of non-redundant information afforded by an individual's network ties facilitates an individual's creative



work productivity because exposure to non-redundant information should stimulate creative thinking. Accordingly, much of social networks research on creativity focuses on the link between individual creativity and the strength of the individual's relationship with others, often referred to as tie strength (McFadyen & Cannella, 2004; Perry-Smith, 2006; Perry-Smith & Shalley, 2003; Ruef, 2002). The strength of an individual's tie is defined as the individual's friendship closeness and interaction frequency with another person (Granovetter, 1973; Marsden & Campbell, 1984). That is, the closer the friendship between two people and/or the more frequently they interact with each other, the stronger the tie between two people. Furthermore, strong ties tend to form between two people who are similar to each other (Brass, Galasskiewicz, Greve, & Tsai, 2004; Byrne, 1971), and they tend to have strong ties to the same set of people such that they are all mutually connected. In contrast, weak ties tend to form between two people who are dissimilar to each other, and weak ties tend to form a bridge between otherwise disconnected parts of the greater social system. Thus, the information received from strong ties is likely to be more redundant than information received from weak ties. Social networks researchers therefore assert that the stronger the tie between two people, the greater the amount of information exchanged between them and subsequently, the more information overlaps between them over time (Granovetter, 1973; Marsden & Campbell, 1984). Thus, by definition, social networks researchers generally assume that redundant information is exchanged across strong ties (e.g. Granovetter, 1973; Perry-Smith, 2006; Uzzi & Spiro, 2005). Consequently, weak ties should facilitate individual creativity more so than strong ties because information exchanged between weak ties is presumably more non-redundant than information exchanged between strong ties (e.g. Perry-Smith & Shalley, 2003).

The research to date, however, does not preclude the possibility that strong ties can also contain non-redundant information. Strong ties containing non-redundant

information are likely to be found in organizational contexts where individuals with highly specialized functional expertise and skills work together on highly interdisciplinary collaborative projects, such as research and development (e.g. nanobiotechnology research laboratory at a university) and product development firms (e.g. Apple and IDEO). In such contexts, since the cross-fertilization of specialized functional expertise and skills is important to creativity (Keller, 2001; Sutton & Hargadon, 1996) but the appropriation of specialized functional expertise and skills is difficult (Hansen, Mors, & Lovas, 2006; Postrel, 2002), tie strength and informational redundancy are likely to be orthogonal constructs. Creative thinking is therefore likely to involve more than a process of simply combining non-redundant information. Creative thinking should involve expending significant effort to think of new and useful ways to combine previously unconnected information and/or to recombine previously connected information (Amabile, 1988; Drazin, Glynn, & Kazanjian, 1999; Nonaka, 1994; Woodman et al., 1993). Specifically, creative thinking in interdisciplinary settings should involve gathering useful non-redundant information, effortful processing of the non-redundant information to glean new insights, and subsequently combining the newly received information with one's own information to generate new and useful ideas or solutions. Thus, the amount of non-redundant information available *alone* does not drive creativity. Instead, creative thinking is contingent on individuals perceiving the usefulness of non-redundant information received from a network tie.

In interdisciplinary contexts, while weak ties certainly contain more non-redundant information than strong ties due to more frequent information exchange between strong ties, strong ties still contain non-redundant information because specialized functional expertise and skills. In such an organizational setting, do individuals consider non-redundant information received from weak ties to be more

useful than non-redundant information received from strong ties? Will non-redundant information received from weak ties prove more influential on an individual's creative thinking than non-redundant information received from strong ties?

### ***Strong Ties and Individual Creative Thinking***

The focus of this chapter is to explore the possibility that strong ties, more so than weak ties, might facilitate individual creative thinking. To this end, I propose a theoretical model that describes two mechanisms that link strong ties to individual creative thinking. I suggest that for an individual's creative thinking to be positively influenced by received non-redundant information, in that the individual learns something new and combines the new insights with his/her own information to generate new ideas or solutions, two things occur.

First, the individual must acknowledge the quality of the received information and such an acknowledgement is likely to be determined by the individual recognizing the quality of the information provider's specialized functional expertise and skills, i.e. competence-based trust (Levin & Cross, 2004; Mayer et al., 1995). Second, to gain new insights and to combine the received information to generate new ideas, the individual must be cognitively open to the influence of the received information. Such cognitive openness is likely to be determined by the individual being comfortable openly discussing the gaps in their own information such that the received information might fill the gaps and/or stimulate a recombination of existing information to fill the gaps. The individual should also be comfortable openly discussing the received information to be able to recognize novel ways to combine the received information with their own information and/or to recombine their own information in novel ways because of gaining new insight from discussing the received information.

This model therefore tests the hypothesis that competence-based trust and openly discussing ideas mediate the link between strong ties and creativity. Additionally, this model also considers whether informational non-redundancy (resulting from functional specialization) moderates the link between the two mediators and individual creativity.

### ***Competence-based Trust and Individual Creative Thinking***

Evidence from social networks research suggests that people perceive non-redundant information received from strong ties to be more useful than non-redundant information received from weak ties because people are more trusting of the intellectual abilities, functional expertise and skills of strong ties (Levin & Cross, 2004; Tsai & Ghoshal, 1998), commonly referred to as competence-based trust (Mayer, Davis, & Schoorman, 1995). Competence-based trust reflects a belief in the quality of the non-redundant information received from strong ties. Strong ties are trusted to be more competent than weak ties because accumulating work experience with each other over time helps people to develop increasingly accurate perceptions of each other's specialized expertise and tacit knowledge, i.e. knowledge that is hard to articulate (Brandon & Hollingshead, 2004; Wegner, 1987; Weick & Roberts, 1993).

As people calibrate to each other's expertise, they become better acquainted with the strengths and weaknesses of the other person's intellectual abilities. Being familiar with the other person's expertise increases the likelihood of asking questions in an appropriate manner such that the other person is more likely to share useful information. Being familiar with the other person's expertise also helps in understanding and learning from the other person's response such that new insights might be gleaned from the other person's expertise. Thus, people perceive non-redundant information from strong ties to be useful because they are more likely to

recognize the quality of the received information. Consequently, in trusting the competence of strong ties, people will learn something new and combine the received information with their own information to generate new ideas or solutions.

### ***Openly Discussing Ideas and Individual Creative Thinking***

In addition to trusting the competence of strong ties, people are also more willing to be influenced by the intentions and actions of strong ties because they believe that strong ties to be motivated by good intentions when they share non-redundant information hold (Levin & Cross, 2004; Tsai & Ghoshal, 1998), i.e. benevolence-based trust (Mayer et al., 1995). Thus, people are more likely to be comfortable revealing what they do not know with strong ties (Levin & Cross, 2004), and thereby be more likely to openly discuss received non-redundant information without being defensive (Lee, 1997); especially those that reflect opposing ideas and perspectives (Lee, Edmondson, Thomke, & Worline, 2004; Tjosvold & Deemer, 1986). In turn, the more the information provider is willing to share non-redundant information to help fill the gaps in the recipient's expertise and knowledge (Ghoshal, Korine, & Szulanski, 1994; Szulanski, 1996). The information provider is also more willing to expend effort in helping the information receiver modify and combine the newly received non-redundant information to generate new ideas (Hansen, 1999; Krackhardt, 1992).

As a result, strong ties are likely to facilitate individual creative thinking because it reflects both a willingness to openly discuss ideas and be cognitively open to each other's views and ideas (Mikulincer & Arad, 1999; Tjosvold & Deemer, 1986). In this instance, openly discussing ideas reflects a mutual respect by which people are comfortable voicing different ideas, perspectives and opinions without fear of evaluative pressures or appearing incompetent to the other person (e.g. Lee et al.,

2004; Sutton & Hargadon, 1996). Thus, by openly discussing differences in a trusting, respectful, supportive, and participative manner (De Dreu & West, 2001; Jehn & Mannix, 2001; Zhou & George, 2001), people are more cognitively open to the influence of non-redundant information received from strong ties than the non-redundant information received from weak ties (Mikulincer & Arad, 1999). In so doing, openly discussing ideas with strong ties should facilitate combining the new insights gained from received non-redundant information with one's own information to generate new ideas or solutions.

In sum, I postulate that strong ties characterized by competence-based trust and openly discussing ideas should facilitate creativity since non-redundant information received from strong ties is more likely to be recognized for its quality and openly discussed which in turn is more likely to positively influence individual creative thinking. Thus, even though weak ties might contain more non-redundant information than strong ties, people trust strong ties to be more competent and well-intentioned than weak ties. Consequently, people are more cognitively open to the influence of non-redundant information received from strong ties and thereby likely combined with their own information to generate new ideas. Thus, strong ties, more than weak ties, should facilitate individual creative thinking. Stated formally:

*Hypothesis 1:*

*Strong ties will facilitate individual creative thinking.*

*Hypothesis 2:*

*Competence-based trust will mediate the link between strong ties and individual creative thinking.*

*Hypothesis 3:*

*Openly discussing ideas will mediate the link between strong ties and individual creative thinking.*

### ***Specialized Functional Expertise and Individual Creative thinking***

The contemporary argument that strong ties hinder creative thinking is based on the premise that information contained in strong ties is redundant because of frequent information exchange. This argument, however, does not preclude strong ties containing non-redundant information because of highly specialized functional expertise and skills, i.e. information non-redundancy that accumulates independently of tie strength. Specialized functional expertise and skills are composed of expertise gained through formal education and experience working in a particular functional domain, i.e. independent of work interactions with others. Thus, regardless of tie strength, a significant amount of informational non-redundancy should exist between two people with different specialized functional expertise in the form of different formal educational and work experiences exposing each individual to different functional knowledge, tools, and skills. Further, even though two people with different functional expertise will exchange knowledge and skills through work interactions, no amount of knowledge and skill exchange will ever result both parties attaining the same level of expertise in each other's functional domain. For instance, no matter how much or how closely a physicist works with a biologist over time, the physicist will never attain as deep an expertise in biology as the biologist, and vice versa. This is because information exchange through work interactions does not substitute for specialized expertise developed through formal education and prior work experiences in a particular domain. Thus, the amount of non-redundant information in a tie varies

with differences in functional expertise between two people, independent of tie strength.

Significant non-redundant information also exists between two people with expertise from the same functional domain. This is because specialized functional expertise consists of unique in-depth knowledge of a functional domain and includes tacit knowledge; i.e. personal know-how that is hard to articulate and entails insights and intuitions gained through subjective experience with a particular function (Nonaka, 1994). For instance, while a biologist who specializes in the regeneration of skin tissue has overlapping general knowledge about biology with the biologist who specializes in the study of cancer cells, both biologists each have unique tacit and in-depth knowledge associated with their specializations. Furthermore, because of tacit knowledge and unique prior work experiences, even two biologists who specialize in the study of cancer cells should have non-redundant information. Therefore, on the one hand, non-redundant information exists between two people from the same functional domain because of differences in tacit knowledge and skills. On the other hand, as suggested earlier, non-redundant information associated with specialized functional expertise exists because two people have expertise in different functional domains. However, while non-redundant information available through highly specialized functional expertise is associated with facilitating creativity (Gilson & Shalley, 2004), the presence of such non-redundant information by itself does not necessarily facilitate individual creative thinking. Rather, individual creative thinking is facilitated only when non-redundant information associated with functional expertise is perceived to be useful and effectively communicated and combined to generate new ideas or solutions (Sternberg & O'Hara, 2000; Taylor & Greve, 2006).

Given that non-redundant information associated with specialized functional expertise exist can exist in two forms (i.e. non-redundancy due to different functional



domains and non-redundancy due to differences in tacit knowledge), what impact might differences or similarities in specialized functional expertise within a tie have on individual creative thinking? To address this question, I consider how differences and similarities in specialized functional expertise might affect (a) the link between competence-based trust and individual creative thinking, and (b) the link between openly discussing ideas individual creative thinking.

### ***Competence-based Trust and Individual Creative Thinking***

In general, the more an individual trusts the competence of another person, the more likely the individual will allow his/her thinking to be influenced by non-redundant information provided by that person. However, competence-based trust could have a larger effect on an individual's creative thinking when he/she receives non-redundant information from a person who has a different functional expertise compared to when receiving non-redundant information from a person with the same functional expertise. When interacting with a person with a different functional expertise, the information recipient has little or no knowledge and ability to evaluate the relevance, quality, and hence the usefulness of the non-redundant information. As a result, the individual will rely on the extent to which he/she trusts the competence of the person with a different functional expertise to determine the extent to which his/her will be influenced by the received non-redundant information.

In contrast, when interacting with a person with the same functional expertise, the information recipient has the relevant expertise to evaluate for himself/herself the relevance, quality, and hence the usefulness of the non-redundant information received. This ability to be more critical with non-redundant information provided by others with the same functional expertise stems from an in-depth understanding of the functional area. As a result, the individual is likely to rely on his/her own assessment

of the quality of received non-redundant information in conjunction with the extent to which he/she trusts the competence of the person with the same functional expertise to determine the extent to which his/her thinking will be influenced by the received non-redundant information. Thus, since the individual can only rely on competence-based trust when assessing the quality of non-redundant information received from a person with a different functional expertise, competence-based trust should have a larger impact on individual creative thinking when receiving non-redundant information from others with a different functional expertise than when receiving non-redundant information from others with the same functional expertise. Stated formally:

*Hypothesis 4:*

*Competence-based trust and similarity in functional expertise will have an interactive effect on individual creative thinking, such that the advantages of competence-based trust will have a greater impact on facilitating individual creative thinking when there is greater dissimilarity in functional expertise between ties.*

### ***Openly Discussing Ideas and Individual Creative Thinking***

Openly discussing ideas facilitates individual creative thinking because the open exchange of different ideas, perspectives and opinions stimulates divergent thinking (Goncalo & Staw, 2006; Lee, 1997). However, openly discussing ideas could have a larger impact on individual creative thinking when the individual interacts with a person with the same functional expertise compared to interacting with a person with a different functional expertise.

While interacting with a person with a different functional expertise certainly facilitates individual creative thinking (Gilson & Shalley, 2004; Taylor & Greve,

2006), the non-redundant information received from a person with different functional expertise is likely to be more rudimentary and less in-depth and tacit than the non-redundant information received from a person with the same functional expertise. This is because the information receiver is likely to lack the requisite expertise to combine in-depth tacit knowledge from a different functional domain. In a similar vein, the information provider is also likely to lack the expertise to be more critical of the information receiver's ideas and therefore likely to share non-redundant information that will constructively challenge the information receiver's ideas to a lesser extent.

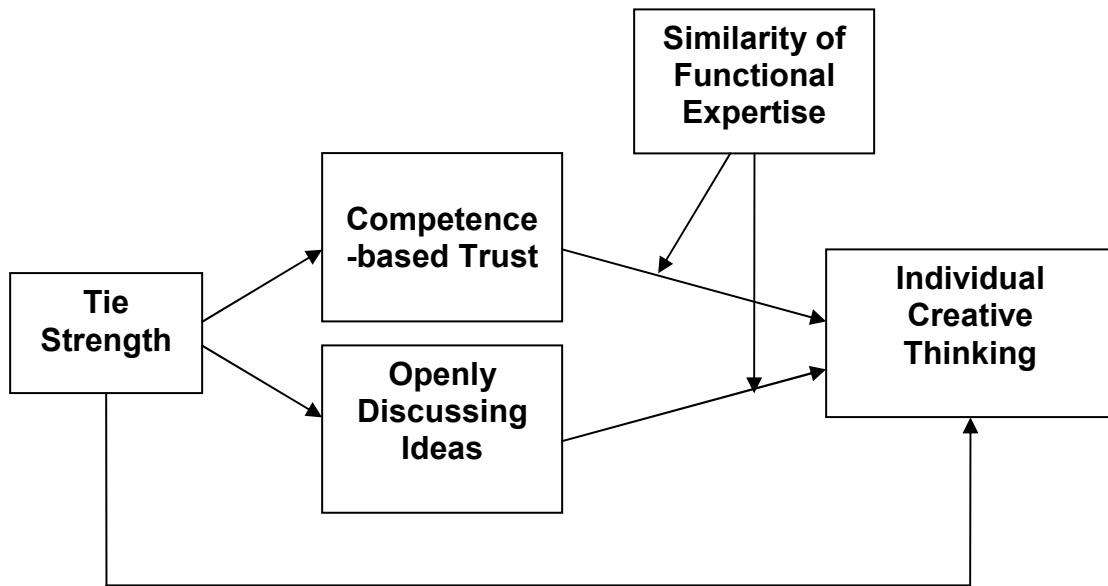
Moreover, the greater the difference in functional expertise, the greater the tendency to openly discuss ideas that are based on commonly held information (Gigone & Hastie, 1993; Stasser & Stewart, 1992; Stasser, Stewart, & Wittenbaum, 1995; Wittenbaum, Hollingshead, & Botero, 2004). This is in part because commonly held information provides a reference point for discussing ideas (Stasser & Stewart, 1992; Gigone & Hastie, 1993). The greater tendency for two people with different functional expertise to engage in openly discussing ideas based on commonly held information is also in part because the more two people voice similar views and opinions, the more the two will perceive each other as intelligent and knowledgeable, as suggested by similarity-attraction theory (Byrne, Clore, & Smeaton, 1986; Tsui & O'Reilly, 1989). Thus, the tendency to engage in openly discussing ideas based on a common reference point likely results in an individual thinking less creatively than he/she might have had he/she engaged the other person in openly discussing ideas based on the in-depth tacit knowledge of their respective functional expertise.

In contrast, individuals are more likely to think more creatively when openly discussing his/her ideas with a person with the same functional expertise because the information provider has the in-depth knowledge to be more critical and therefore more likely to share non-redundant information that constructively challenges the

information recipient's thinking. Moreover, having the same functional expertise indicates a significant amount of commonly held information which suggests that openly discussing ideas will facilitate the sharing of non-redundant information in the form of in-depth tacit knowledge. Openly discussing ideas should also facilitate the information receiver's effectiveness at combining the received tacit knowledge with his/her own knowledge to generate new ideas or solutions. Thus, openly discussing ideas will have a greater impact on facilitating individual creative thinking when interacting with a person who has the same functional expertise compared to when interacting with a person who has a different functional expertise. Stated formally:

*Hypothesis 5:*

*Openly discussing ideas and similarity in functional expertise will have an interactive effect on individual creative thinking, such that the advantages of openly discussing ideas will have a greater impact on facilitating individual creative thinking when there is greater similarity in functional expertise between ties.*



**Figure 1: Theoretical Model linking Tie Strength to Individual Creative Thinking**

In sum, I propose a model linking strong ties to individual creative thinking (see Figure 1). I suggest that strong ties should facilitate individual creative thinking because strong ties reflect competence-based trust and openly discussing ideas. I argue that that competence-based trust and openly discussing ideas directs the processing of non-redundant information such that learning results in new insights gained and combined with existing knowledge to generate new ideas. Thus, one might expect that the individual with a greater number of strong ties will have more opportunities to think creatively through social interaction and thereby be more creative at the person-level.

*Hypothesis 6:*

*The number of strong ties an individual maintains will positively predict person-level individual creativity.*

## CHAPTER 2

### GROUP CREATIVITY AND SOCIAL NETWORK TIES

Group creativity is the process of combining members' ideas and knowledge to generate novel and useful work outcomes (Amabile, 1996; Drazin et al., 1999; George, 2007; Shalley et al., 2004; Woodman et al., 1993). Group creativity therefore consists of the psychological mechanisms underlying the interactions between group members as they combine or re-configure their pooled knowledge to generate new and useful ideas or solutions. A second aspect reflects the group's productivity in implementing these ideas and solutions to produce creative work outcomes. Group creativity therefore consists of two interrelated but distinct constructs: Group creative processing and the production of group creative work outcomes.

To date, an extensive range of research has significantly contributed to our understanding of how group creativity is affected by within-group characteristics such as brainstorming processes (McGlynn et al., 2004; Paulus & Yang, 2000; Sutton & Hargadon, 1996), functional composition (Keller, 2001; Lovelace, Shapiro, & Weingart, 2001; Taylor & Greve, 2006), membership change (Choi & Thompson, 2005), minority influence (Nemeth, 1986; Nemeth & Nemeth-Brown, 2003), work structure (Gilson & Shalley, 2004; Gilson, Mathieu, Shalley, & Ruddy, 2005; Taggar, 2002), and values (Goncalo & Staw, 2006). For instance, the more groups adopt individualistic values, the more each group member will generate ideas that diverge from other members' ideas; thus leading to greater group creativity (Goncalo & Staw, 2006). Moreover, the effect within-group characteristics have on group creativity is not restricted to idea generation. Researchers have studied how within group characteristics affect the combination of ideas. For instance, the more each member in a comic book writing team has experience working with different comic book genres,

the greater the team's ability to combine members' diverse ideas and knowledge, and thereby the more creative the joint work (Taylor & Greve, 2006). Together, these studies suggest that the more within-group characteristics support creative processes such as generating and combining divergent ideas (Guilford, 1956), the greater group creativity. Thus, since tie strength affects the exchange and combination of information between two people, what might we learn about group creative processing and group creative work outcomes if we considered the collective effect of all existing dyadic ties within a group?

In this chapter, I address this question by first considering the link between group tie strength density (i.e. total tie strength of all existing dyadic ties between group members as a fraction of the maximum possible tie strength between group members) and group creative processing. Because the group-level constructs of trust, cooperative norms, and psychological safety have all been postulated [but as yet empirically tested] to facilitate creativity, I consider the hypothesis that group-level trust, cooperative norms, and psychological safety will mediate the link between group tie strength density and group creative processing.

In recognizing that group creative processing does not necessarily lead to the successful implementation of ideas and solutions to produce creative work outcomes, I also consider the condition when group creative processing leads to group creative work outcomes and the condition when it does not. Because group creativity is a process of combining group member's ideas and knowledge, conflict (i.e. perceived or real differences) between member's ideas and perspectives surely accompany group creativity. I therefore consider the moderating effect of conflict on the link between group creative processing and group creative work outcomes.

### ***Group Tie Strength Density and Group Creativity***

To date, social networks researchers who have studied group creativity focus their analysis primarily on the effects of network structure (Guimera, Uzzi, Spiro, & Amaral, 2005; Uzzi & Spiro, 2005). In essence, the basic argument from this research is the same as the variety of networks research focusing on the link between tie strength and individual creativity (McFadyen & Canella, 2004; Perry-Smith, 2006; Perry-Smith & Shalley, 2003; Rodan & Galunic, 2004; Ruef, 2002). That is, social networks research on group creativity in general emphasizes that the more network ties provide access to non-redundant information, the more group creativity will occur. Given this overlap, and since the link between tie strength and informational redundancy has been articulated identically across non-creativity networks research on individual and group performance (e.g. Granovetter, 1973; Hansen, et al., 2006; Hansen, 1999, 2002; Reagans & Zuckerman, 2001), it only seems natural that considering the link between group tie strength and group creativity will contribute to our understanding of the link between within-group characteristics and group creativity.

However, the link between group tie strength and group creative processing is not identical to the link between dyadic tie strength and individual creative thinking. This is because group level creative processing is not simply an aggregate of the creative thinking of each individual member. Instead, group creative processing is the aggregate of the creative processing that occurs *between* two group members, for all existing dyadic relationships within the group (Hargadon & Bechky, 2006; Paulus & Yang). This definition is consistent with conceptualizations of group creativity that emphasize the aggregation of creative processing that emerge from dyadic social interactions (Hargadon & Bechky, 2006; Paulus & Yang, 2000), as opposed to group creativity as the aggregation of individual creative abilities (e.g. Taggar, 2002).



Furthermore, because groups are often different in size and that not all group members have the same tie strength to other members of the group, I consider the effect of group tie strength density on group creativity rather than just total group tie strength.

Group tie strength density is a collective construct representing the total tie strength of all existing dyadic ties between group members, i.e. the actual interaction frequencies and friendship closeness between any two members, as a fraction of the maximum possible interaction frequency and friendship closeness between group members. Group tie strength density therefore represents the collective effect of the dyadic relationships that serve as conduits by which creative processing occurs between group members.

To conceptualize how group tie strength density might affect group creative processing, I suggest thinking about group creative processing as a two-step process. First, each individual member combines non-redundant information [received from interactions with other group members] with their own information to generate new ideas, and collectively, these ideas forms the pool of ideas from which the group will generate new ideas and solutions. Even though these ideas collectively represent the entire range of possible ideas that the group can work with, these ideas may not ultimately be used or even be known to the other group members since these ideas reside in each individual member's mind and subsequently may or may not be shared with other members. The second step of group creative processing involves the sharing of ideas between members in that members learn something new and gain new insights and the shared ideas are combined to generate new ideas and solutions.

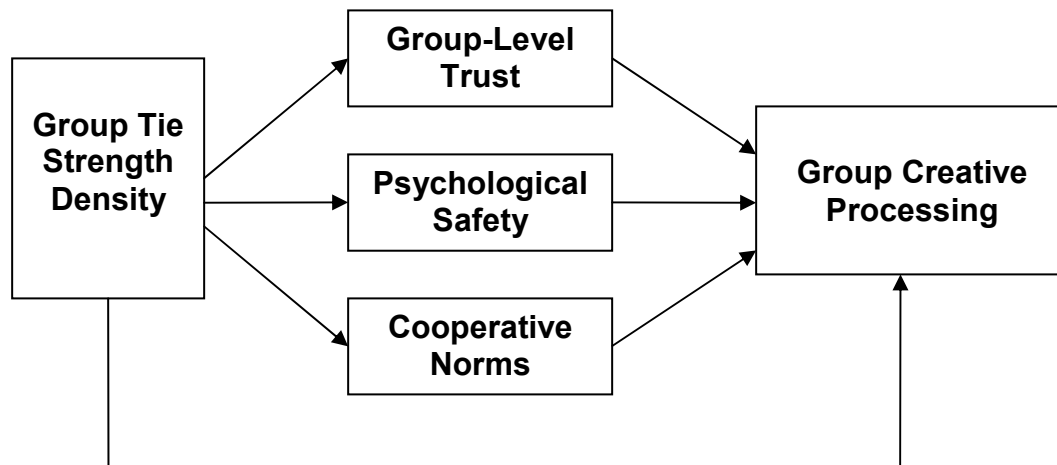
Thus, the frequency and manner by which members interact, exchange, and combine ideas with each other collectively determines the extent of group creative processing. For instance, in an effort to examine the cognitive processes underlying the generation of creative ideas, Dugosh, Paulus, Roland, and Yang (2000) found that

individuals who were motivated to attend to a flow of ideas from others produced more creative ideas than individuals who were not paying the same attention to others' ideas. Further, Okhuysen and Eisenhardt (2002) point out that even though creative potential resides in the ideas of individual members, this creative potential is realized by combining these ideas through within-group processes such as information sharing and questioning other group members. Thus, in generating new and useful outcomes from combining group members' ideas, groups face the challenge of stimulating divergent thinking processes such that members' unique and dissimilar ideas are shared and combined to form new ideas.

Divergent thinking processes occur when group members focus their attention on multiple ideas that are dissimilar, i.e. from different general categories (Goncalo & Staw, 2006; Guilford, 1956). By contrast, convergent thinking processes occur when group members focus their attention on multiple ideas that are similar, i.e. ideas of the same general category. Thus, groups engage in divergent thinking processes by focusing their attention on the dissimilar ideas shaped by non-redundant information exchanged between within-group ties. These diverse ideas are subsequently combined through cross-pollination to generate new ideas (Amabile, 1996; Sutton & Hargadon, 1996; Woodman et al., 1993). Groups, however, do not necessarily engage in divergent thinking processes because members do not always share those ideas that are dissimilar and non-redundant (Wittenbaum, Merry, & Stasser, 1996; Wittenbaum, Hollingshead, & Botero, 2004). Group members may withhold these ideas for fear of damaging their reputation, appearing incompetent, or engaging in conflict. Thus, the dyadic tie-relationships between members should collectively allow members to actively voice their unique ideas without encroaching on the team's ability to get work done (Sutton & Hargadon, 1996), even if it means being aggressive or stubborn in defending unique perspectives to bring about change and improvement (Lipman-

Blumen & Leavitt, 1995). This suggests that the extent to which groups realize their synergistic potential for creative processing depends on how dyadic social interactions collectively lead to group level relational mechanisms that support the demands of divergent thinking.

The stronger a group's tie strength density, the more the group should experience cooperative norms, group-level trust, and psychological safety; all of which have been previously suggested to facilitate group creativity (e.g. Collins & Smith, 2006; Edmondson, 1999; Flynn & Chatman, 2001). Thus, I consider the hypothesis that group-level trust, psychological safety, and cooperative norms will mediate the link between group tie strength density and group creative processing (See Figure 2.).



**Figure 2: Theoretical Model linking Group Tie Strength Density to Group Creative Processing**

### ***Group-Level Trust and Group Creative Processing***

There are two possible reasons why trust forms within groups with strong tie strength density. Firstly, individuals connected by strong within-group ties tend to develop similar attitudes, thinking styles, and use similar jargon to communicate information (Walker, 1985). According to similarity-attraction theory (Byrne, Clore, & Smeaton, 1986; Tsui & O'Reilly, 1989), the more two people think and communicate in a similar fashion, the more intelligent and knowledgeable they consider each other, and therefore trust should form within groups with strong tie strength density. Consequently, individuals members might perceive non-redundant information more closely related to what they know to be more useful than those that are different; even if dissimilar non-redundant information was originally sought to gain a different perspective (e.g. Heath & Gonzalez, 1995). In this way, trust should lead to lesser efforts in creatively processing non-redundant information exchanged between strong within-group ties (McEvily, Perrone, & Zaheer, 2003; Uzzi, 1997).

However, as individuals within a group accumulate work interactions with each other over time, group members will develop increasingly accurate perceptions of each other's specialized expertise and tacit knowledge, i.e. knowledge that is hard to articulate (Brandon & Hollingshead, 2004; Wegner, 1987; Weick & Roberts, 1993). As group members calibrate to each others' expertise, they become better acquainted with the strengths and weaknesses of each others' intellectual abilities. Thus, the trust in groups with strong tie strength density is more likely to be formed on familiarity with each member's specialized functional expertise and skills (i.e. competence-based trust) than on being similar in thinking and communication. Moreover, being familiar with each member's expertise increases the likelihood of asking questions in an appropriate manner such that groups with strong tie group density are more likely to share useful information. Thus, competence-based trust facilitates understanding and

learning within groups with strong tie strength density such that new insights might be gleaned from each others' expertise.

In addition to trusting the competence of strong ties, people also believe strong ties to be motivated by good intentions when they share non-redundant information, i.e. benevolence-based trust (Levin & Cross, 2004; Mayer et al., 1995). Thus, group members should be more willing to reveal their shortcomings in expertise and knowledge (Lee, 1997), and thereby be willing to be influenced by the other group members. In turn, the more group members are willing to reveal their shortcomings, the more within-group ties are willing to share non-redundant information to help fill the gaps in each other's expertise and knowledge (Ghoshal, Korine, & Szulanski, 1994; Szulanski, 1996). Within-group ties are also more willing to expend effort in helping the information receiver understand and effectively use the newly received non-redundant information to generate new ideas (Hansen, 1999; Krackhardt, 1992).

As a result, group-level trust is a likely explanation linking strong group tie density to group creative processing. Stated formally:

*Hypothesis 7:*

*Group-level trust will mediate the link between group tie strength density and group creative processing.*

### ***Psychological Safety and Group Creative Processing***

Group creative processing could be perceived by group members as risky since it requires them to voice unique ideas that may or may not be rejected by group members, to learn from others and thereby risk revealing their shortcomings, and in working with unfamiliar information to generate new ideas also puts them at risk of revealing their incompetence. Thus, group members can perceive risk in one of three

ways. First, openly sharing non-redundant information and voicing unique ideas can be a daunting experience for individual members. This is because in sharing unique ideas, individual members are likely to feel a sense of embarrassment associated with a concern about being seen as different, or worse still as incompetent (Edmondson, 1999). Second, learning something new and gaining new insights from the non-redundant information provided by other team members can reveal or make salient individual member's mistakes or gaps in their knowledge and expertise. Third, in combining new information with what they know to generate new ideas could also reveal the limitations in individual members' knowledge skills. For example, individual members are at risk of making mistakes or doing a poor job when working with unfamiliar information. Modifying one's own ideas and knowledge to accommodate new insights gleaned from other member's ideas can lead individual members to experience feelings of inadequateness or a sense of being a "follower" (Menon, Thompson, & Choi, 2006). All of which represent interpersonal risks.

Thus, for a group to realize the benefits of group creative processing, group members must have a shared belief that it is safe to take such interpersonal risks when interacting with other group members, commonly known as psychological safety (Edmondson, 1999). In this instance, psychological safety reflects a mutual respect by which group members are comfortable voicing different ideas, perspectives and opinions without fear of evaluative pressures or appearing incompetent to other group members (e.g. Lee et al., 2004; Sutton & Hargadon, 1996). This is not to say that psychological safety reflects cohesiveness because cohesiveness represents the shared belief of consensus building with little or no disagreement and dissent, e.g. groupthink (Janis, 1972). Rather, psychological safety represents a shared belief that not only is disagreement and dissent valuable to learning and gaining new insights, members who disagree will be respected and valued for their dissenting views and will not be

embarrassed, rejected, or sanctioned for dissenting (Edmondson, 1999). Furthermore, like most group-level constructs, the development of psychological safety in a group stems from group members who, in working together over time, have shared experiences in making mistakes and achieving successes such that the group converges on the shared belief that it is acceptable to make mistakes. Thus, strong group tie density should be positively related to psychological safety which in turn should facilitate group creative processing. Stated formally,

*Hypothesis 8:*

*Psychological safety will mediate the link between group tie strength density and group creative processing.*

### ***Cooperative Norms and Group Creative Processing***

Combining non-redundant information is as important, if not more important, as the sharing of non-redundant information to group creative processing. Often times, individual group members have very different opinions and views from each other about which idea is the most creative amongst those that were collectively generated by the group (Goncalo & Staw, 2006). This difference in opinions is especially evident with interdisciplinary groups. Thus, in looking to find a good resolution to these differences in opinions and views, groups often choose to combine a variety of ideas to form a new composite idea instead of selecting one idea from the pool. This approach often results in the generation of the most creative ideas, be it by design or accident.

Norms researchers suggest that establishing cooperative norms will facilitate group creativity (e.g. Chatman & Flynn, 2001). This is because cooperative norms emphasize group goals. Cooperative groups will be more efficient and effective at

combining the different ideas offered by group members in generating new ideas. In contrast, uncooperative groups will be less effective at creative processing because they will be distracted by member's disagreements about the proper way to select and combine ideas (Bettenhausen & Murnighan, 1985). That is, uncooperative groups are less effective at creative processing because they are so caught up in trying to resolve disagreements about the right way to solve problems creatively that they inadvertently spend significantly less time on creative processing itself.

Furthermore, when uncooperative norms prevail, group members tend to be more self-interested, lack commitment to the group goals, and have a general focus on self-achievement (Chatman & Flynn, 2001). As such, uncooperative groups are less likely to share and exchange non-redundant information; and they are less likely to put in the requisite effort necessary to integrate members' ideas and knowledge to generate new ideas. Thus, the research on group norms suggests that cooperative groups are more likely than uncooperative groups to process information creatively. Since effective cooperative norms tend to be established in groups where members have extensive experience working with each other, cooperative norms should mediate the link between strong group tie density and group creative processing. Stated formally,

*Hypothesis 9:*

*Cooperative norms will mediate the link between group tie strength density and group creative processing.*

I further consider the link between group creative processing and group creative work outcomes. As argued earlier, group creative processing and group creative work outcomes are interrelated but distinct constructs. This is because



contextual factors such as budget constraints and technology limitations can hinder a group's ability to implement effectively the ideas and solutions generated from group creative processing. In addition, social factors such as group conflict - generally defined as the process or awareness by which individual members of a group acknowledge the tension resulting from real or perceived differences about relationship or task issues (De Dreu & Weingart, 2003; Jehn & Mannix, 2001) - can also hinder a group's ability to implement effectively the ideas and solutions generated from group creative processing. When a group is engaged in creative processing, it is essentially in a state of endless possibilities. The group has at its disposal a set of ideas and solutions from which they can choose one idea or combine different ideas to generate the one idea to pursue implementation. Alternatively, the group could be dissatisfied with the existing pool of ideas and decide to continue generating more new ideas and solutions. Either way, when a group is engaged in creative processing, it presents itself with a variety of opportunities to produce creative work outcomes. To produce creative work outcomes, the group must choose one idea to pursue implementation. However, groups engaged in creative processing may face considerable difficulty finding consensus in choosing one idea to implement (Goncalo & Staw, 2006). This difficulty could be driven by differences in opinions and interpersonal differences about which ideas to choose and how to proceed with ideas implementation, i.e. task and relationship conflict respectively (De Dreu & Weingart, 2003; Jehn & Mannix, 2001). Thus, in the next section, I consider how conflict might moderate the link between group creative processing and group creative work outcomes.

### ***The Moderating Effect of Conflict on the link between Group Creative Processing and Group Creative Work Outcomes***

The link between group creative processing and the production of creative work outcomes may not be a direct, linear one. This is because group creative processing is often accompanied by conflict. Conflict accompanies group creative processing in at least two ways. First, because group creative processing involves the exchange and combination of non-redundant information and different ideas and opinions, conflict regarding the task of integrating different opinions as well as conflict associated with interpersonal tension can arise. Second, task and relationship conflict can also arise not so much at the creative idea generation phase but at the implementation phase. That is, while group creative processing may have proceeded with little or no conflict, the implementation phase of turning the creative ideas into useful solutions or products can be laden with conflict. Thus, while some dimensions of conflict, e.g. cognitive conflict, is often positively associated with group creativity (e.g. Jehn & Bendersky, 2003), other dimensions of conflict may prove detrimental to group creativity. In this section, I consider the instance where task- and relationship-based conflict adversely affects group creative outcome productivity when both conflict and group creative processing is high.

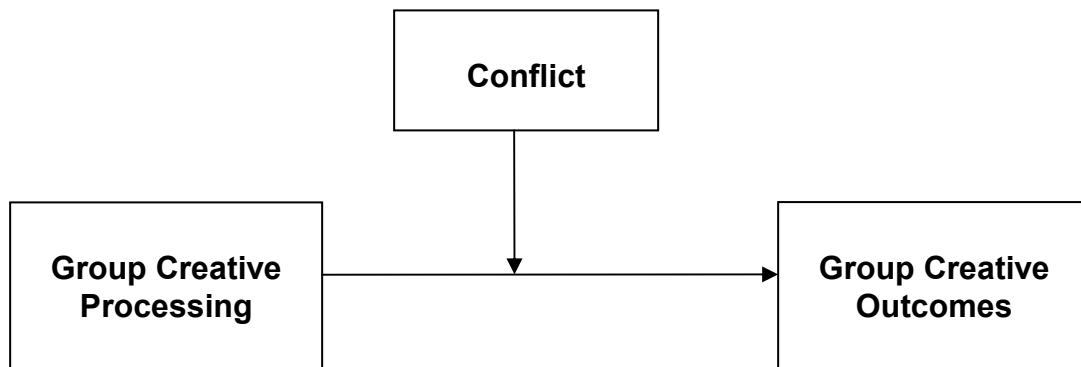
Task conflict is defined as conflict driven by differences in ideas regarding the task being performed, whereas relationship conflict is defined as conflict arising from interpersonal differences, hostility, and annoyance between individuals (Jehn & Mannix, 2001). Task conflict in groups, however, is often manifested as emotionally charged dissent (Pelled, 1996) and subsequently misinterpreted as personal attacks, thus leading to relationship conflict (Simons & Peterson, 2000). Furthermore, most studies that examine task and relationship conflict typically report a significant positive relationship between the two (Simons & Peterson, 2000). This suggests that

successfully implementing creative ideas to produce group creative outcomes might be less about promoting task conflict in the absence of relationship conflict but more about minimizing task and relationship conflict by resolving disagreements in a trusting, respectful, supportive, and participative manner (De Dreu & West, 2001; Zhou & George, 2001).

Alternatively, it is possible that the task and relationship conflict accompanying group creative processing is borne of ongoing disagreement and dissatisfaction with the existing ideas and solutions (Amabile, Barsade, Mueller, & Staw, 2005; George & Zhou, 2002) and not borne of conflict in implementation. A heightened sense of dissent and dissatisfaction, manifested as emotional tension, could drive individual members' efforts and persistence in thinking creatively at the detriment of implementing already existing ideas (Amabile et al., 2005; George & Zhou, 2002; Zhou & George, 2001). Groups experiencing emotional tension and conflict during creative processing are likely to interpret the tension as an indication that group members remain discontent with the ideas being discussed and thus persist in their creative efforts to change and improve their ideas. While this could benefit group creative processing and subsequently benefit group creative outcomes, a prolonged discontent with the ideas could inadvertently send the group into an endless spiral of disagreement and dissent such that members may become so defensive and imbued with their own unique perspectives such that a prolonged active consideration of dissenting ideas hampers the production of group creative outcomes (See Figure 3.).

*Hypothesis 10:*

*Group creative processing and conflict will have an interactive effect on group creative outcomes, such that the advantages of group creative processing will be realized when conflict is low.*



***Figure 3: Theoretical Model linking Group Creative processing to Group Creative Outcome***

In sum, the motivation of this chapter is to contribute to our understanding of the link between within-group characteristics and group creativity. Building on the argument that group creativity is better understood in terms of the collect impact of the creativity occurring through dyadic level interactions (Hargadon & Bechky, 2006; Paulus & Yang, 2000), I consider the hypothesis that the group-level constructs of trust, cooperative norms, and psychological safety will mediate the link between strong tie group density and group creative processing. Moreover, since conflict accompanies group creativity, I suggest that conflict affects the implementation aspect of group creativity. Hence, I further consider the moderating effect of conflict on the link between group creative processing and group creative work outcomes. In the next chapter, I present a study designed to empirically test these hypotheses (as well as the hypotheses in chapter 1) in an organizational setting characterized by interdisciplinary work where creativity is important to work productivity and success.

## CHAPTER 3

### CREATIVITY IN A NANOBIO TECHNOLOGY R&D LABORATORY

This study was conducted with a group of 30 scientists working in a nanobiotechnology research and development laboratory at a large northeastern university. Preliminary interviews with the laboratory director confirmed that in addition to getting grants and publications, the daily scientific work done in this setting is interdisciplinary and creativity plays an important role in work productivity and success. Creativity is important both as a process and as an outcome because biologists, physicists, chemists, and engineers work together on different collaborative projects addressing a variety of basic and applied problems in the biological sciences. One area of collaborative work uses protein engineering and expression techniques for developing recombinant anti-cancer therapeutics. A second area involves the design and engineering of portable sensor devices using nanofabrication methods. A third area explores how to use biomaterials to develop new methods for creating advanced microfluidic systems and nanostructured arrays for bioanalytical applications. Creativity is thus important to work in this setting in that work productivity depends on the scientists being able to combine cross-disciplinary knowledge to develop new ideas, solutions, and tools to investigate basic and applied problems in the biological sciences.

This setting also provided an advantage in that it was possible to adopt a full roster method to collect complete network data. Since a full roster method requires each participant to report about their relationships with everybody else in the network, collecting complete network data can be difficult and impractical. Depending on the type and number of questionnaire items each participant responds to for each dyadic relationship, the full roster method has typically been adopted for networks ranging in

size approximately between 20 and 40 people (e.g. Borgatti & Cross, 2003; Krackhardt, 1987, 1995; Casciaro, 1998; Casciaro, Carley, & Krackhardt, 1999). The full roster method has also been used to examine larger networks (> 50 people) but these studies had to limit their measures of dyadic relationships. For instance, one study relied on single item measures of communication frequency and friendship (Labianca, Brass, & Gray, 1998), and another study relied on participants going through the entire roster and putting a check beside each name for two items indicating similar social identity and friendship (Mehra, Kilduff, & Brass, 1998). Given the challenges associated with collecting data on complete social networks, this setting of 30 scientists should be adequate. Therefore, this setting provided an advantage in that I could collect multi-item measures of different aspects of each dyadic relationships as well as a corresponding multi-item measure of creative processes. Furthermore, at the time of data collection, the laboratory had 30 distinctive ongoing group-level projects. Each group project involved between 2 to 9 scientists ( $M_{\text{members}} = 3.67$ ,  $SD_{\text{members}} = 2.02$ ). Thus, in addition to the complete network data, this setting also provided me with the opportunity to collect group-level data to examine group creativity both as a process and as an outcome.

### *Sample*

The 30 scientists in the laboratory consisted of 2 senior scientists (one of which is the laboratory director), 5 research associates, 4 postdoctoral fellows, 13 graduate students, and 6 undergraduate students. Because the undergraduate students were fully engaged in working on the projects, e.g. contributing to discussions on research design and running experiments, and not merely providing supporting work, e.g. cleaning equipment and entering data, they were included in the sample of scientists. The average scientist was 27 years old ( $M_{\text{age}} = 27.33$ ,  $SD_{\text{age}} = 7.30$ ) and had worked in this

laboratory for 3 years ( $M_{\text{tenure}} = 3.27$ ,  $SD_{\text{tenure}} = 3.69$ ). 33 percent of the scientists were female. Ethnically, this group of scientists comprised Asians (23 percent), African Americans (10 percent), Caucasian Americans (53 percent), and Latin Americans (13 percent).

Since the laboratory director was apriori designated to evaluate the creativity of group projects, he was not surveyed on any of the network or group-level measures to mitigate the risk of common source variance. Thus, 29 scientists were surveyed. Of these 29, 26 completed all the surveys (a 90 percent response rate). The remaining two scientists completed the network surveys but provided incomplete responses on the group-level surveys; and their network data were included in the analysis where appropriate. The one scientist that did not turn in any surveys turned out to occupy a peripheral position in the network and thus it is reasonable to assume that missing data from this scientist would not affect the present analysis. Furthermore, while the laboratory director and one scientist did not provide any network data, their names were still included on the full roster. As such, out of 30 scientists, 28 scientists (93 percent) provided complete data on network structure of the laboratory. These 28 scientists reported an average of approximately 19 network ties ( $M_{\text{no. of ties}} = 19.64$ ,  $SD_{\text{no. of ties}} = 7.38$ ), yielding a complete network with 550 dyadic relationships in total. Thus, the network data collected in this study should be representative of the whole network structure.

### ***Data Collection***

I collected data using a combination of full roster network and survey methods administered in five phases, each approximately a month apart. Data collection was spaced a month apart for several reasons. First, because a full roster social networks approach requires participants to answer each survey question for every single

member of the organization, the number of survey items each participant responds gets very large very quickly. For example, in a network of 30 scientists, answering a 2-item measure of trust already requires each participant to respond to 58 survey items. Thus, to attain a finer grained measure of the relational mechanisms underlying network relationships using a full roster approach demands quite an effort on the part of the participant, which can lead to data collection problems associated with fatigue and disengagement. Similarly, each individual scientist worked on multiple projects which meant that each participant responded to group-level survey questions for every group he/she worked on. Again, problems like fatigue and disengagement are highly likely. Therefore, spacing out data collection helps mitigate these risks. Secondly, because the various independent, mediating and dependent variables were conceptualized at different levels of analysis (i.e. individual, dyadic, and group levels) and causal direction was implied, the number and order of data collection phases helps to ensure that variables are measured at the right level of analysis and to establish some (though admittedly non-conclusive) evidence of causal direction. For example, because tie strength data was conceptualized at the dyadic level of analysis, collecting data at different phases a month apart also helps mitigate the risk of common method variance. The scientists reported requiring between 30 and 60 minutes to complete each survey. They were guaranteed confidentiality and all surveys were returned directly to me or a research assistant not affiliated with the laboratory.

*Phase 1.* In the first phase, survey data on demographic variables were collected. The scientists responded to questions on age, country of origin, ethnicity, educational level, functional expertise, gender, position, previous work experiences, and years worked at the laboratory. In addition, the scientists were instructed to list all the projects they were currently working on ( $M_{\text{no. of projects}} = 2.80$ ,  $SD_{\text{no. of projects}} = 1.69$ ). They also listed down the names of the collaborators for each project. The project and



collaborator names lists were collected to prepare the surveys for group-level measures to be collected in phase 3.

*Phase 2.* For the second phase, I used a full roster network method to elicit each scientist's unique set of dyadic relationships (Scott, 2000; Wasserman & Faust, 1994). That is, each scientist was presented a list of the names of all the members of the laboratory. The scientists were then instructed to use a multi-item 7-point scale to rate their relationship with each laboratory member in terms of tie strength, competence-based trust, and openly discussing ideas (see Appendix A). They were further instructed to rate all members on one item before rating everyone on the next item, and so on. Having the scientists take a list-wise approach to rate everyone on one item before rating everyone on the next item served two purposes. This made for a less tedious experience responding to multiple survey items for 29 distinct relationships. It also had the added benefit of mitigating inter-item bias since this list-wise approach requires respondents to rate the other 28 relationships before rating a particular relationship on a different item.

Each scientist responded to four questions assessing tie strength. Two questions assessed them approaching others: "How frequently do you have work-related interactions with this person?" and "To what extent do you consider this person a close friend?". The other two questions assessed others approaching them: "How frequently does this person have work-related interactions with you?" and "To what extent does this person consider you a close friend?"

For competence-based trust, each scientist responded to two questions: "How much do you trust this person's intellectual abilities?" and "How often do you seek work-related advice from this person because this person is an expert in his/her research area?". For openly discussing ideas in each tie, each scientist responded to two questions. For example, "How comfortable are you openly discussing your ideas

with this person?” and “How comfortable are you critically discussing this person’s ideas?”.

*Phase 3.* In the third phase, I collected group-level measures using survey methodology. Using the project and collaborator names lists collected in phase 1, each scientist responded to questions measuring group-level conflict, cooperative norms, trust, and psychological safety for each of the collaborative projects they listed in phase 1 (see Appendix B). For conflict, the scientists responded to nine questions, e.g. “How much personal friction is there amongst members when working on this project?” and “To what extent is there conflict about how work is being done amongst project members?”. For cooperative norms, the scientists responded to four questions, e.g., “How much cooperation is there among project members” and “How much collaboration is there among group members?”. For trust, the scientists responded to eight questions, e.g. “To what extent are members certain that they can fully trust each other when working on this project?” and “To what extent do members seek help from each other when faced with difficulties at work?”. For psychological safety, the scientists responded to seven questions, e.g. “If you make a mistake, how often do the rest of the members hold it against you?” and “To what do members reject others for being different?”. Furthermore, to mitigate inter-item bias, the scientists answer each question for all the different collaborative projects they worked on before responding to the next question.

*Phase 4.* For the fourth phase, I also used a full roster network method to collect data on individual creative thinking that occurs when interacting with a network tie. For individual creative thinking, each scientist was asked to rate the extent to which the following occurs when he/she interacted with each person on the laboratory: (1) useful non-redundant information is received, (2) effortful processing of non-redundant information, (3) new insights gained through learning, and (4)

combining newly received information to generate new and useful ideas. Example survey questions include “How often do you learn something new from information shared by this person?” and “To what extent do you combine information shared by this person with your own information to generate new ideas?” (See Appendix C for all items).

*Phase 5.* Finally, in the fifth phase, I collected data on individual creativity in terms of peer and supervisor evaluations of an individual’s overall creativity. Each scientist, including the laboratory director, evaluated each and every person on a 5-item scale measuring individual creativity, e.g. “To what extent does this person generate original ideas compared to others in the laboratory?” and “How often does this person’s original ideas lead to good solutions?”. I also collected data on group creativity from supervisor ratings. The laboratory director evaluated all the collaborative projects on a 6-item scale, e.g. “Overall, this is a very original project” and “This project uses new techniques to solve existing problems more effectively than existing techniques.” See appendix D for all the measures used for individual creativity and group creative outcomes.

### ***Dependent Variable Measures***

*Dyadic-Level Individual Creative Thinking.* I used an 8-item scale to measure individual creativity thinking as a process of combining useful non-redundant information received from a network tie to generate new and useful ideas. To my knowledge, there are no preexisting measures of individual creative thinking in management theory. As such, I constructed a new 8-item scale by drawing on a combination of cognitive and organizational theories of the creative process (e.g. Amabile, 1988; Drazin et al. 1999; Dunbar, 1997; Hargadon & Bechky, 2006; Simonton, 2003). Two items related to receiving non-redundant information (e.g. To

what extent does this person share information you do not already know?), two items related to mindful consideration of received information (e.g. How much effort do you put into thinking about information shared by this person?), two items related to gaining new insights (e.g. How rarely do you gain new insights from information shared by this person? - reverse coded), and two items related to combining received information with one's own information to generate new ideas (e.g. To what extent do you combine information shared by this person's with your own information to generate new ideas?)(see Appendix C). Factor analysis using varimax rotation indicated that all eight items loaded onto one factor with factor loadings ranging from 0.80 to 0.94 and 78.05 percent of the variance accounted for. Cronbach's alpha for this 8-item scale was 0.96.

*Person-Level Peer and Supervisor rated Individual Creativity.* Building on previous theoretical work and empirical measures of individual creativity (Amabile, 1988; Zhou & George, 2001), I constructed a 5-item scale to measure individual creativity (see Appendix D). One item related to expertise in a research area, one item related to stimulating creative thinking in others, and three items related to producing original ideas and creative work. Factor analysis using varimax rotation indicated that all five items loaded onto one factor with factor loadings ranging from 0.90 to 0.97 and 87.60 percent of the variance accounted for. Cronbach's alpha for this 5-item scale was 0.96. For peer-rated individual creativity, because the inter-rater agreement was good (ICC = 0.95), I averaged across all raters to form an aggregate measure of peer-rated individual creativity for each scientist. For supervisor-rated individual creativity, I used the laboratory director's ratings on the same 5-item scale.

*Group Creative Outcomes (Project Creativity).* I measured group creative outcomes using a 6-item scale relevant to this organizational setting (see Appendix E). Three items related to the novelty of the project (e.g. This project has the potential to

generate novel solutions.) and three items related to the usefulness of the project (e.g. Overall, the project will make a valuable contribution to biology.). Factor analysis using varimax rotation indicated that all six items loaded onto two factors with factor loadings ranging from 0.79 to 0.93 and 78.01 percent of the variance accounted for. Cronbach's alpha for this 5-item scale was 0.83.

### ***Independent Variable Measures***

*Tie Strength.* A widely accepted practice in social network research is to conceptualize and operationalize *tie strength* in terms of interaction frequency and relationship closeness (e.g. Granovetter, 1973; Hansen, 1999; Marsden & Campbell, 1983; Perry-Smith, 2006). Following this norm, I measured tie strength by combining responses on items pertaining to frequency of work-related interactions and closeness of relationships. However, social network researchers mostly rely on subjective measures of tie strength. Thus, following recent work on advice and information networks (e.g. Borgatti & Cross, 2003; Cross & Cummings, 2004), I used an estimate pooling technique to mitigate potential response bias in measuring tie strength.

The first step entails assessing agreement between person *i* and person *j* on each of the two tie strength dimensions: Work interaction frequency and friendship closeness. For work interaction frequency, agreement was assessed between *i*'s response to the question "How frequently do you have work-related interactions with person *j*?" and *j*'s response to the question "How frequently does person *i* have work-related interactions with you?". Since inter-rater agreement was good (ICC = 0.84), I averaged the responses on these 2 questions as a bi-directional measure of work interaction frequency. For friendship closeness, agreement was assessed between *i*'s response to the question "To what extent do you consider person *j* a close friend?" and *j*'s response to the question "To what extent does person *i* consider you a close

friend?”). Since inter-rater agreement was good ( $ICC = 0.81$ ), I averaged the scores on these 2 questions as a bi-directional measure of friendship closeness.

Next, I assessed the agreement between work interaction frequency and friendship closeness. Since agreement was good ( $ICC = 0.82$ ), I averaged the work interaction frequency score with the friendship closeness score to construct a *bi-directional measure of tie strength* for i’s relationship to j. In addition to mitigating potential response bias, a benefit of this bi-directional measure of tie strength also mitigates the concern of common method variance in measuring tie strength and measuring the proposed mediator variables in the same phase, i.e. phase 2 of this study. Unlike tie strength, the mediating variables were constructed on subjective measures because I am testing a model proposing that the link between tie strength and creativity is mediated by i’s trust in j’s competence and i’s comfort in being open with j.

*Competence-based Trust.* I adapted items used by previous work on trust relationships (Mayer et al. 1995; McAllister, 1995). Specifically, two items were adapted to measure the trust in the tie’s intellectual abilities and expertise in the field he/she works in. The two items were “How often do you seek work-related advice from this person because this person is an expert in his/her research area?” and “How much do you trust this person’s intellectual abilities?”.

*Openly Discussing Ideas.* Two items were used to measure the extent to which an individual is comfortable openly discussing his/her own ideas and critically discussing the other person’s ideas.. The items were “how comfortable are you openly discussing your ideas with this person?” and “How comfortable are you critically discussing this person’s ideas?”

*Similarity of Functional Expertise (Information Non-Redundancy).* Building on previous social networks research (e.g. Reagans & McEvily, 2003), *information*

*non-redundancy* was assessed by constructing a dummy variable of functional expertise in a tie (1 = different functional expertise, 0 = same functional expertise). Thus, zero indicates informational redundancy, whereas one indicates informational non-redundancy. Although informational redundancy could also be operationalized as a continuous variable, the differences between functional expertise were difficult to properly. For instance, while being in “biomedical engineering” is different from being in “materials engineering” as is being in “electrical engineering” is different from being in “chemical engineering”, it is near impossible to determine if the respective differences were comparable in magnitude. Hence, I felt it would be more prudent to categorizing functional expertise dichotomously (i.e. same versus different).

*Person-Level Strong/Weak Ties.* While I have theorized and measured tie strength as a continuous variable to empirically test the link between tie strength and individual creativity, previous work only looked at between individual creativity and the number of strong/weak network ties, i.e. they have only used a dichotomous measure of tie strength (Perry-Smith, 2006; Ruef, 2004). Hence, since I hypothesized a relationship between the number of ties and individual creativity, I dichotomized ties into strong and weak ties. In this instance, by dichotomizing an otherwise continuous measure of tie strength also allows for a suitable comparison between the results from this study and to the previous studies (e.g. Perry-Smith, 2006; Ruef, 2004). Since I used a bi-directional measure of tie strength that ranged from 1 (weak) to 7 (strong), I categorized ties with a strength of less than 4 as weak and tie strength of at least 4 as strong ties.

*Group Tie Strength Density.* To construct a measure of group-level tie strength density, I summed up the tie strength of all the dyadic ties for that project group and divided this total by the maximum amount of tie strength possible for the same group.

This approach to measuring group-level ties strength density takes into account the number of members in a group project. Thus, by calculating total group-level tie strength as a proportion of the maximum possible tie strength, comparisons between groups of different size is meaningful..

*Group Creative Processing.* To construct a measure of group-level creative thinking, I used the same estimate pooling technique mentioned earlier in the section on dyadic-level tie strength. The first step entailed assessing agreement between person i and person j on their respective ratings of creative thinking ( $ICC = 0.74$ ). An average was then taken of the ratings person i and person j. The pooled values for both items were combined to construct a *bi-directional measure of creative processing* at the dyadic-level. I then summed up the creative processing of all the dyadic ties for that project group and divided this total by the maximum amount of creative processing possible for the same group. Like group-level tie strength density, this approach to measuring group-level creative processing density takes into account the number of members in a group project. Thus, by calculating total group creative processing as a proportion of the maximum possible creative processing, comparisons between groups of different size is meaningful.

*Cooperative Norms.* I constructed a 4-item by adapting from previous work on cooperative norms (Chatman & Flynn, 2001). Factor analysis using varimax rotation indicated that all four items loaded onto one factor with factor loadings ranging from 0.89 to 0.92 and 82.43 percent of the variance accounted for. Cronbach's alpha for this 4-item scale was 0.93. Because the inter-rater agreement amongst group members was good ( $ICC = 0.87$ ), I averaged across all member's ratings to form an aggregate measure of group-level cooperative norms.

*Group-Level Trust.* I constructed an 8-item group-level scale by drawing on previous theoretical and empirical work that has measured trust (Jehn & Mannix,



2001; Mayer et al., 1995; McAllister, 1995; Simons & Peterson, 2000). Factor analysis using varimax rotation indicated that all eight items loaded onto one factor with factor loadings ranging from 0.73 to 0.94 and 75.83 percent of the variance accounted for. Cronbach's alpha for this 8-item scale was 0.94. Because the inter-rater agreement amongst group members was good ( $ICC = 0.95$ ), I averaged across all member's ratings to form an aggregate measure of group-level trust.

*Psychological Safety.* I used Edmondson's (1999) scale to measure psychological safety. Factor analysis using varimax rotation indicated that the seven items loaded onto two factors with factor loadings ranging from 0.53 to 0.94 and 79.74 percent of the variance accounted for. Cronbach's alpha for this 7-item scale was 0.89. Despite the inter-rater agreement amongst group members was somewhat weak for one factor ( $ICC = 0.47$ ) and reasonable for the other factor ( $ICC = 0.68$ ), I averaged across all member's ratings on the two factors to form an aggregate measure of group-level psychological safety because this scale is the standard measure of psychological safety (Edmondson, 1999).

*Group-Level Conflict.* I drew on recent research on conflict (Jehn & Mannix, 2001; Peterson & Behfar, 2003) to construct a 9-item scale to measure group-level conflict. Factor analysis using varimax rotation indicated that all eight items loaded onto one factor with factor loadings ranging from 0.79 to 0.94 and 77.00 percent of the variance accounted for. Cronbach's alpha for this 8-item scale was 0.96. Because the inter-rater agreement amongst group members was good ( $ICC = 0.78$ ), I averaged across all member's ratings to form an aggregate measure of group-level conflict.

*Group Functional Diversity.* I used Blau's index (Blau, 1977; Reagans & Zuckerman, 2004) to calculate functional diversity because this form of diversity has been conceptualized as "variation" diversity (Harrison & Klein, 2007). Variation diversity is defined as diversity that is composed of differences in "kind, source, or

category of relevant knowledge or experience” among group members (Harrison & Klein, 2007: 1203).

### ***Control Variables***

*Dyadic-Level Control Variables.* To control for people’s affinity to engage in social interaction with similar others (homophily), I included control variables assessing whether there was tie homophily in terms of age (continuous), gender (dummy), ethnicity (dummy), position (dummy), and tenure (continuous).

*Group-Level Control Variables.* To control for other forms of group diversity that may also have an effect on group creativity, I included control variables assessing group diversity in age (continuous), gender (dummy), ethnicity (dummy), position (dummy), and tenure (continuous). For age, tenure, and position, I used the coefficient of variation (Allison, 1978; Chatman & Flynn, 2001; Randel & Janussi, 2003) to calculate diversity because these forms of diversity have been conceptualized as “disparity” diversity (Harrison & Klein, 2007). Disparity diversity is defined as diversity composed of differences in “proportion of socially valued assets or resources” held by group members. For gender and ethnicity, I used Blau’s index (Blau, 1977; Reagans & Zuckerman, 2004) to calculate diversity because these forms of diversity have been conceptualized as “variation” diversity (Harrison & Klein, 2007).

Since some scientists were involved in more than one project, I also controlled for overlapping membership in projects by creating a dummy variable for each scientist that worked on more than one project (1 = person *i* works on this project, 0 = otherwise). In addition, there were a number of projects ( $n = 7$ ) that previously had members that were no longer with the laboratory at the time of data collection, I also controlled for these alumni (1 = alumnus worked on this project, 0 = otherwise).

## Results

### *Tie Strength and Individual Creative Thinking*

I analyzed the data on tie strength and individual creative thinking by using hierarchical linear modeling. Descriptive statistics, internal reliabilities, and simple correlations among variables used in the analyses are reported in Tables 1 and hierarchical linear modeling statistics are presented in Table 2.

**Table 1: Means, Standard Deviations, Correlations, and Internal Reliabilities<sup>a</sup> for Individual Creative Thinking.**

Variable	<u>M</u>	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1. Individual Creative Thinking	2.55	2.20	<b>.97</b>											
2. Age homophily	6.93	5.94	.11											
3. Gender homophily	0.53	0.50	.17	.09										
4. Ethnicity homophily	0.30	0.46	.01	.17	-.03									
5. Position homophily	0.76	0.43	-.11	.33	-.11	.07								
6. Education homophily	0.69	0.46	.03	.24	.04	-.05	.36							
7. Tenure homophily	2.56	.352	.17	.75	.05	.15	.17	.02						
8. Functional Expertise	0.89	0.32	-.06	-.02	-.05	.04	.06	.02	-.06					
9. Tie strength	3.08	1.81	.64	.02	.21	.00	-.18	.03	.05	-.11	<b>.80</b>			
10. Competence-based trust	3.67	2.39	.66	.08	.11	.04	-.10	.13	.11	-.07	.69	<b>.84</b>		
11. Openly Discuss Ideas	3.69	2.54	.62	.02	.11	-.04	-.13	.08	.03	-.06	.72	.76	<b>.93</b>	
12. Competence-based trust * Functional Expertise	3.20	2.54	.52	.05	.06	.06	-.05	.13	.04	.45	.52	.81	.62	
13. Open Discuss Ideas * Functional Expertise	3.22	2.68	.49	.00	.08	-.03	-.77	.09	.00	.43	.57	.62	.84	.81

<sup>a</sup>*n* = 504. Internal reliabilities are presented along the diagonal in bold.

Two-tailed tests: Correlations greater than .09 are significant at  $p < 0.05$ , and correlations greater than .11 are significant at  $p < 0.01$ .

To test the hypothesis that the strength of a tie influences an individual's creative thinking, I used hierarchical linear modeling (HLM). This is because in collecting network tie data from the entire network, there is non-independence in that information providers give information to multiple people whereas the information receiver receives information from multiple sources. To run HLM, I created two higher level variables, one to take into account the non-independence of information providers and the other variable to take into account the non-independence of information receivers. In addition, HLM also takes into account the interaction effect of both of the higher level variables. HLM is much like running an ordinary least squares simple regression with the exception that HLM does not assume independence of observations. Despite this important difference, interpreting hierarchical linear modeling estimates is much the same as interpreting ordinary least squares regression estimates (see Table 2). With this in mind, I present the HLM analyses in the following sections.

**Table 2: Hierarchical Linear Modeling Results<sup>a</sup> for Individual Creative Thinking**

Variable	Individual Creative Thinking				
	Model 1	Model 2	Model 3	Model 4	Model 5
Same age control	-0.00 (0.03)	0.00 (0.02)	0.00 (0.02)	0.00 (0.02)	0.00 (0.02)
Same gender control (dummy)	-0.64** (0.19)	-0.15 (0.15)	-0.40** (0.14)	-0.25 (0.14)	-0.26 (0.14)
Same ethnicity control (dummy)	-0.01 (0.21)	0.06 (0.17)	0.06 (0.16)	0.09 (0.15)	0.11 (0.15)
Same position control (dummy)	0.77** (0.25)	0.14 (0.20)	0.12 (0.19)	0.04 (0.18)	0.03 (0.18)
Same education control (dummy)	-0.35 (0.23)	-0.06 (0.18)	0.26 (0.17)	0.21 (0.17)	0.19 (0.17)
Same tenure control	0.12** (0.04)	0.09 (0.03)	0.07* (0.03)	0.07* (0.03)	0.07 (0.03)
Functional Expertise Similarity (dummy)	0.22 (0.30)	-0.15 (0.24)	-0.03 (0.22)	-0.13 (0.22)	-0.98* (0.47)
Tie strength		0.76*** (0.04)		0.35*** (0.06)	0.35*** (0.06)
Competence-based trust			0.40*** (0.05)	0.31*** (0.05)	0.14 (0.14)
Openly discussing Ideas			0.24*** (0.04)	0.13** (0.05)	0.49*** (0.14)
Competence trust * functional expertise similarity					0.19 (0.15)
Open discuss Ideas * functional expertise similarity					-0.40** (0.16)
-2 restricted log likelihood	2227.46	1963.85	1910.60	1880.701	1876.59
Degrees of freedom	496	495	494	493	492
Variable	Competence-based trust		Openly Discussing Ideas		
	Model 6	Model 7	Model 8	Model 9	
Same age control (dummy)	-0.01 (0.03)	-0.01 (0.02)	-0.01 (0.03)	-0.00 (0.02)	
Same gender control (dummy)	-0.35 (0.21)	0.23 (0.16)	-0.43 (0.23)	0.22 (0.16)	
Same ethnicity control (dummy)	-0.28 (0.23)	-0.19 (0.17)	0.15 (0.25)	0.24 (0.17)	
Same position control (dummy)	1.00*** (0.27)	0.25 (0.20)	1.00** (0.29)	0.16 (0.21)	
Same education control (dummy)	-1.06*** (0.25)	-0.72 (0.18)	-0.76 (0.27)	-0.38* (0.19)	
Same tenure control	0.10* (0.05)	0.06 (0.03)	0.05 (0.05)	0.01 (0.03)	
Functional Expertise Similarity (dummy)	0.43 (0.33)	-0.02 (0.24)	0.35 (0.35)	-0.15 (0.25)	
Tie strength		0.90*** (0.04)		1.02*** (0.05)	
-2 restricted log likelihood	2286.052	1984.330	2359.723	2017.426	
Degrees of freedom	496	495	496	495	

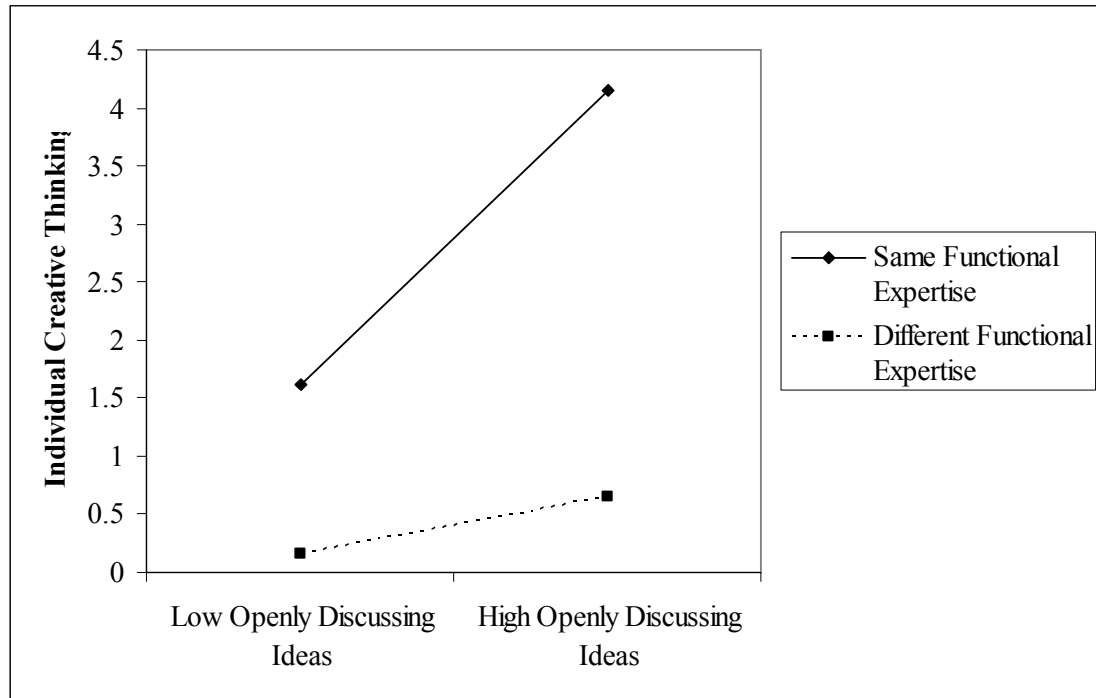
<sup>a</sup> $n = 504$ . Unstandardized coefficients shown with errors in parentheses\* $p < 0.05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

Hypothesis 1 predicts that the strength of a tie will be positively related to individual creative thinking such that non-redundant information received from strong ties are more likely to be perceived as useful in that new insights are gained and combined to generate new ideas or solutions. As predicted by hypothesis 1, model 2 shows tie strength did have a positive and statistically significant ( $\beta = 0.76$ ,  $t = 17.77$ ,  $p < 0.001$ ) overall effect on individual creative thinking.

Hypotheses 2 and 3, respectively, predict that competence-based trust and openly discussing ideas will mediate the link between tie strength and individual creative thinking. As predicated by hypothesis 2 and 3, all four steps of the standard Baron & Kenny (1986) approach to mediation analysis were met to demonstrate that competence-based trust and openly discussing ideas mediate the link between tie strength and individual creative thinking (see Table 2). First, model 2 shows tie strength had a positive and statistically significant ( $\beta = 0.76$ ,  $t = 17.77$ ,  $p < 0.001$ ) overall effect on individual creative thinking. Second, models 7 and 9 show tie strength had a positive effect on the two mediators: competence-based trust ( $\beta = 0.90$ ,  $t = 20.56$ ,  $p < 0.001$ ) and openness ( $\beta = 1.02$ ,  $t = 22.38$ ,  $p < 0.001$ ). Third, model 3 shows that competence-based trust ( $\beta = 0.40$ ,  $t = 8.64$ ,  $p < 0.001$ ) and openness ( $\beta = 0.24$ ,  $t = 5.65$ ,  $p < 0.001$ ) each had a positive effect on individual creative thinking. Fourth, model 4 shows that including both mediators in the HLM analysis shows a statistically significant effect of competence-based trust ( $\beta = 0.31$ ,  $t = 6.65$ ,  $p < 0.001$ ) and openly discussing ideas ( $\beta = 0.13$ ,  $t = 2.91$ ,  $p < 0.01$ ) on individual creative thinking while the positive effect of tie strength on individual creative thinking remains ( $\beta = 0.35$ ,  $t = 5.90$ ,  $p < 0.001$ ). Finally, Sobel's (1982) test confirmed each of the mediating relationships were statistically significant: competence-based trust ( $z = 6.23$ ,  $p < 0.001$ ) and openly discussing ideas ( $z = 2.87$ ,  $p < 0.01$ ).

Hypothesis 4 predicted that differences in specialized functional expertise within a network tie would moderate the link between competence-based trust and individual creative thinking. However, model 5 shows that the interaction effect is statistically non-significant in that competence-based trust is positively related to individual creative thinking regardless of informational redundancy in a network tie (see Table 2).

Hypothesis 5 predicted that informational redundancy (through functional expertise) in a network tie would moderate the link between openly discussing ideas and individual creative thinking. Model 5 shows that openly discussing ideas has a statistically significant main effect on individual creative thinking ( $\beta = 0.49$ ,  $t = 3.55$ ,  $p < 0.001$ ). As predicted, this main effect is qualified by a statistically significant interaction effect with informational redundancy in the network tie ( $\beta = -0.40$ ,  $t = -2.73$ ,  $p < 0.01$ ) (see Table 2). To examine the nature of this interaction, I inserted both values for informational redundancy (same functional expertise = 0 and different functional expertise = 1) into model 5 and tested the statistical significance of the slope for each value while controlling for everything else (Bauer & Curran, 2005). When there is informational redundancy in a tie, openly discussing ideas had a statistically significant effect ( $\beta = 0.49$ ,  $t = 3.55$ ,  $p < 0.001$ ; see figure 4). When there is informational non-redundancy in a tie, openly discussing ideas did not have a statistically significant effect. Thus, openly discussing ideas had a larger impact on individual creative thinking when two people from the same functional expertise interact with each other.



**Figure 4: Moderating Effect of Functional Expertise Differences on Individual Creative Thinking**

#### ***Person-level Peer and Supervisor-rated Individual Creativity***

Hypothesis 6 predicts that the number of strong ties positively relates to person-level individual creative thinking. In addition to the widely used approach of using supervisor-ratings of person-level individual creativity, I also tested this hypothesis using peer-ratings of person-level individual creativity. The number of strong ties was positively related to both supervisor-rated ( $\beta=0.11$ ,  $t=2.61$ ,  $p < 0.02$ ) and peer-rated ( $\beta=0.16$ ,  $t=2.94$ ,  $p < 0.02$ ) person-level individual creativity. In contrast, the number of weak ties was not significantly related to either supervisor-rated ( $\beta=0.02$ ,  $t=0.68$ ,  $p > 0.50$ ) or peer-rated person-level individual creativity



( $\beta=0.04$ ,  $t=0.32$ ,  $p > 0.75$ ). Thus, as predicted, the number of strong ties is positively related to person-level individual creativity.

***Group-level Trust, Cooperative Norms, and Psychological Safety as Mediators linking Group Tie Strength Density to Group Creative Processing***

To test the hypotheses linking group tie strength density to group creative processing and the hypotheses linking group creative processing to creative group outcomes, I used ordinary least squares regression analyses. Descriptive statistics, internal reliabilities, and simple correlations among variables used in these analyses are reported in Table 3.

**Table 3: Means, Standard Deviations, Correlations, and Internal Reliabilities<sup>b</sup> for Group Creativity.**

Variable	<u>M</u>	SD	1	2	3	4	5	6	7	8	9	10	11	12
1. Group Creative Outcome	3.98	.81	<b>.83</b>											
2. Group Creative Process	0.31	.08	.03											
3. Age diversity	0.19	.12	-.35	.16										
4. Gender diversity	0.28	.22	-.02	-.28	.20									
5. Ethnicity diversity	0.39	.26	.07	-.41	.19	.44								
6. Position diversity	0.40	.17	.07	-.12	.67	.45	.39							
7. Tenure diversity	0.58	.37	-.19	.09	.86	.06	.06	.65						
8. Group Tie Strength Density	0.33	.08	.08	.73	.02	-.48	-.20	-.19	.07					
9. Group Level Trust	5.47	.73	.10	.60	.29	-.32	-.18	-.09	.21	.58	<b>.94</b>			
10. Norms (Cooperative)	5.36	.84	.17	.56	.11	-.20	-.17	-.09	.04	.45	.81	<b>.93</b>		
11. Psych Safety	5.74	.72	.29	.44	.03	-.23	-.10	-.13	-.02	.55	.75	.66	<b>.89</b>	
12. Conflict	2.20	.85	-.32	-.39	.12	.01	.15	.22	.10	-.37	-.59	-.39	-.65	<b>.96</b>

<sup>b</sup> $n = 30$ . Internal reliabilities are presented along the diagonal in bold.

Two-tailed tests: Correlations greater than .36 are significant at  $p < 0.05$ , and correlations greater than .55 are significant at  $p < 0.01$ .

The group-level data is also non-independent since each organizational member is involved in multiple projects. To account for this non-independence, I gave each member a dummy code and thereby controlled for the effects of individual members to run an ordinary least squares regression analysis (see tables 4a and 4b).

**Table 4a: Ordinary Least Squares Linear Regression Results<sup>b</sup> for Group Creative Processing**

Variable	Group Creative Processing							
	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17
Member overlap control	not reported	not reported	not reported	not reported	not reported	not reported	not reported	not reported
Age diversity control	-0.00 (0.03)	0.38 (0.16)	-0.06 (0.32)	0.30 (0.23)	0.19 (0.29)	-0.06 (0.32)	0.13 (0.38)	0.24 (0.40)
Gender diversity control	-0.64** (0.19)	0.12 (0.10)	-0.04 (0.16)	0.11 (0.11)	-0.02 (0.16)	-0.04 (0.16)	-0.09 (0.20)	0.04 (0.25)
Ethnicity diversity control	-0.01 (0.21)	-0.09 (0.11)	0.16 (0.19)	-0.05 (0.14)	0.13 (0.19)	-0.05 (0.13)	0.06 (0.23)	-0.09 (0.29)
Position diversity control	0.77** (0.25)	-0.12 (0.16)	-0.28 (0.29)	-0.15 (0.18)	-0.34 (0.29)	-0.17 (0.18)	-0.28 (0.29)	-0.24 (0.38)
Tenure diversity control	-0.35 (0.23)	-0.11 (0.06)	0.79 (0.11)	-0.09 (0.08)	0.08 (0.11)	-0.08 (0.08)	0.79 (0.11)	-0.03 (0.15)
Group tie strength density		0.93** (0.15)		0.82* (0.25)		0.80* (0.24)		0.82* (0.25)
Group-level trust			0.09* (0.30)	0.02 (0.03)				
Coop Norms					0.06* (0.21)	0.01 (0.02)		
Psych Safety							0.07 (0.04)	0.07 (0.04)
Adjusted R <sup>2</sup>	-0.10	0.83	0.49	0.81	0.50	0.81	0.21	0.18
$\Delta R^2$	0.20	0.23	0.16	0.23	0.16	0.23	0.10	0.12
Degrees of freedom	5	1	1	2	1	2	1	2

<sup>b</sup>*n* = 30. Unstandardized coefficients shown with errors in parentheses  
 \**p* < 0.05; \*\**p* < .01; \*\*\**p* < .001

**Table 4b: Ordinary Least Squares Linear Regression Results<sup>b</sup> for Group Creative Processing (continued)**

Variable	Group-level Trust		Cooperative Norms		Psych Safety	
	Model 18	Model 19	Model 20	Model 21	Model 22	Model 23
Member overlap	not reported	not reported	not reported	not reported	not reported	not reported
Age	5.15	4.94	3.47	3.17	4.15	4.01
diversity	(3.49)	(2.39)	(5.07)	(3.58)	(3.84)	(3.63)
Gender	-1.52	0.59	-2.57	0.43	-1.41	0.04
diversity	(1.88)	(1.47)	(2.74)	(2.20)	(2.07)	(2.23)
Ethnicity	-1.48	-2.29	-1.72	-2.89	-1.72	-1.11
diversity	(2.29)	(1.60)	(3.33)	(2.39)	(3.33)	(2.42)
Position	2.00	1.82	3.89	3.64	0.37	0.25
diversity	(3.45)	(2.36)	(5.01)	(3.54)	(3.7.)	(3.58)
Tenure	-1.00	-1.70	-1.48	-2.48	-0.56	-1.05
diversity	(1.29)	(0.92)	(0.19)	(1.37)	(1.42)	(1.39)
Group tie strength density		6.55* (2.19)		-0.02* (0.24)		4.51 (3.32)
Adjusted R <sup>2</sup>	0.001	0.53	-0.63	0.19	-0.26	-0.12
$\Delta R^2$	0.32	0.14	0.25	0.23	0.21	0.07
Degrees of freedom	5	1	5	1	5	1

<sup>b</sup> $n = 30$ . Unstandardized coefficients shown with errors in parentheses

\* $p < 0.05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

Hypothesis 7 predicted that group-level trust would mediate the link between group tie strength density and group creative processing. Steps 1-3 of the standard Baron & Kenny (1986) approach to mediation analysis were met (see Tables 4a and 4b). First, model 11 shows group tie strength density had a positive and statistically significant overall effect on group creative processing ( $\beta = 0.93$ ,  $t = 6.21$ ,  $p = 0.001$ ). Second, model 19 show group tie strength density had a positive effect on group-level trust ( $\beta = 6.55$ ,  $t = 2.19$ ,  $p < 0.05$ ). Third, model 12 shows that group-level trust had a positive effect on group creative processing ( $\beta = 0.09$ ,  $t = 3.03$ ,  $p < 0.05$ ). Fourth, model 13 shows that including both group tie strength density and group-level trust in the regression analysis shows that group tie strength density remains statistically

significant ( $\beta = 0.82$ ,  $t = 3.27$ ,  $p < 0.05$ ) but not group-level trust ( $\beta = 0.02$ ,  $t = 0.57$ ,  $p > 0.59$ ). However, Sobel's (1982) test indicates that group-level trust does mediate the link between group tie strength density and group creative processing ( $z = 2.14$ ,  $p < 0.05$ ).

Hypothesis 8 predicted that psychological safety would mediate the link between group tie strength density and group creative processing. However, only step 1 of the standard Baron & Kenny (1986) approach to mediation analysis was met (see Tables 4a & 4b), i.e. group tie strength density had a positive and statistically significant overall effect on group creative processing ( $\beta = 0.93$ ,  $t = 6.21$ ,  $p = 0.001$ ). Model 11 shows step 2 was not met since group tie strength density did not have an effect on psychological safety ( $\beta = 4.51$ ,  $t = 1.36$ ,  $p > 0.20$ ). Model 16 shows that step 3 was not met since psychological safety did not have an effect on group creative processing ( $\beta = 0.07$ ,  $t = 1.94$ ,  $p > 0.09$ ). Finally, Sobel's (1982) test confirms that psychological safety does not mediate the link between the link between group tie strength density and group creative processing ( $z = 1.11$ ,  $p > 0.25$ ).

Hypothesis 9 predicted that cooperative norms would mediate the link between group tie strength density and group creative processing. Steps 1-3 of the standard Baron & Kenny (1986) approach to mediation analysis were met (see Tables 4a and 4b). First, model 11 shows group tie strength density had a positive and statistically significant overall effect on group creative processing ( $\beta = 0.93$ ,  $t = 6.21$ ,  $p = 0.001$ ). Second, model 21 shows group tie strength density had a positive effect on cooperative norms ( $\beta = 9.31$ ,  $t = 2.84$ ,  $p < 0.05$ ). Third, model 14 shows that cooperative norms had a positive effect on group creative processing ( $\beta = 0.06$ ,  $t = 3.04$ ,  $p < 0.05$ ). Fourth, model 15 shows that including both group-level tie strength and cooperative norms in the regression analysis shows group tie strength density remains statistically significant ( $\beta = 0.80$ ,  $t = 3.35$ ,  $p < 0.05$ ) but not cooperative

norms ( $\beta = 0.01$ ,  $t = 0.73$ ,  $p > 0.49$ ). However, Sobel's (1982) test indicates that cooperative norms does mediate the link between group tie strength density and group creative processing ( $z = 2.08$ ,  $p < 0.05$ ).

That step 4 in the standard Baron & Kenny (1986) approach is not met for both hypotheses 7 and 9, it does not necessarily indicate that a mediation relationship does not exist. This is because step 4 is a necessary requirement only if a full mediation is expected (Kenny, Kashy, & Bolger, 1998). Expecting a full mediation from a single mediator is especially unrealistic in explaining psychological behavior (MacKinnon, Fairchild, & Fritz, 2007). Furthermore, it is quite possible that the statistical results for step 4 in this instance indicate a misspecification of the causal order (MacKinnon, Fairchild, & Fritz, 2007). For example,  $X_{\text{tie strength}} \rightarrow M_{\text{cooperative norms}} \rightarrow Y_{\text{creative thinking}}$  versus  $Y_{\text{creative thinking}} \rightarrow M_{\text{cooperative norms}} \rightarrow X_{\text{creative thinking}}$ . Indeed, Sobel's (1982) test, a more conservative test which assumes the  $X \rightarrow M$  and  $M \rightarrow Y$  links to be independent, indicates that group-level trust and cooperative norms do mediate the link between group tie strength density and group creative processing.

### ***Moderating Effect of Conflict linking Group Creative Processing to Group Creative Outcomes***

Hypothesis 10 predicted that conflict would moderate the link between group creative processing and group creative outcome such that group creative thinking is positively related to group creative outcomes when conflict is low. Regression analyses shows that group creative processing had a significant main effect on group creative outcomes ( $\beta = 20.81$ ,  $t = 3.73$ ,  $p < 0.05$ ), and as predicted, this main effect was qualified by an interaction with conflict ( $\beta = -9.90$ ,  $t = -3.39$ ,  $p < 0.05$ ) (see Table 5).

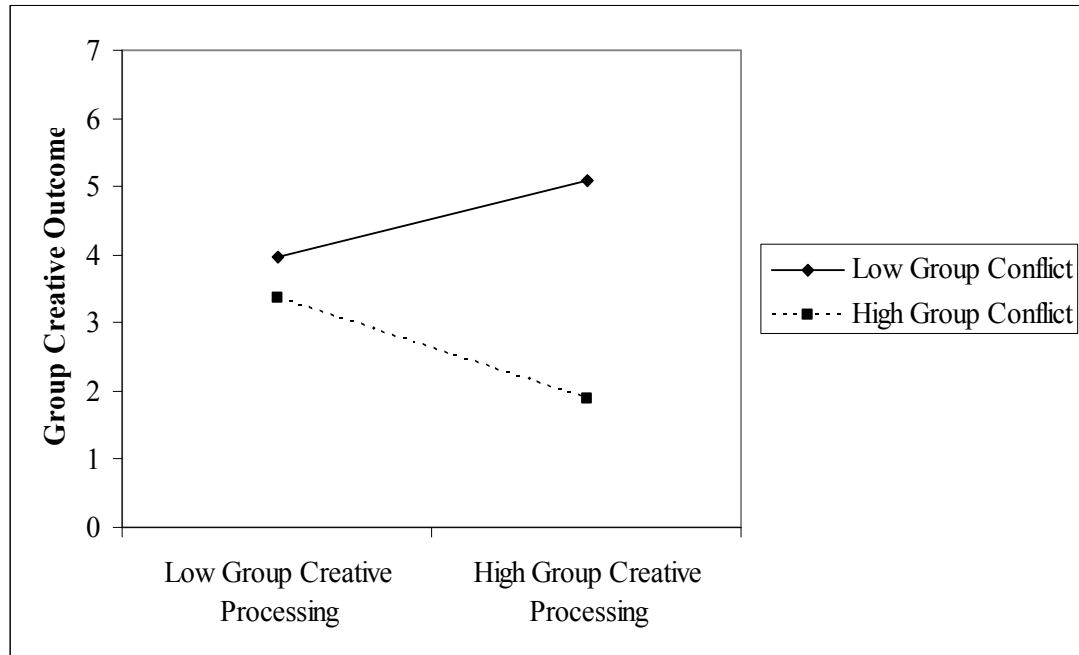
**Table 5: Ordinary Least Squares Linear Regression Result<sup>b</sup> for Group Creative Outcome**

Variable	Group Creative Outcome					
	Model 24		Model 25		Model 26	
Membership overlap	not reported		not reported		not reported	
Age diversity control	-3.09	(3.91)	-5.75	(2.85)	-10.06**	(2.06)
Gender diversity control (dummy)	0.12	(2.11)	0.10	(1.54)	1.04**	(0.92)
Ethnicity diversity control (dummy)	1.99	(257)	3.11	(1.82)	1.97	(1.08)
Position diversity control (dummy)	-3.02	(3.86)	-2.53	(2.63)	-4.05	(1.56)
Tenure diversity control	0.27	(1.44)	0.65	(0.99)	3.02	(0.90)
Group Creative Processing			2.56	(2.59)	20.81*	(5.58)
Conflict			-0.70 <sup>†</sup>	(0.04)	1.95	(0.80)
Creative processing * conflict					-9.90*	(2.92)
Adjusted R <sup>2</sup>	-0.04		0.52		0.85	
$\Delta R^2$	0.24		0.17		0.06	
Degrees of freedom	5		2		1	

<sup>b</sup> $n = 30$ . Unstandardized coefficients shown with errors in parentheses

<sup>†</sup> $p < 0.06$ ; \* $p < 0.05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

To examine the nature of this interaction, I inserted a high and a low value for conflict (one standard deviation above and below the mean) into model 26 and tested the statistical significance of the slope for each value while controlling for everything else (Bauer & Curran, 2005).



**Figure 5: Moderating Effect of Conflict on Group Creative Outcomes**

When conflict is one standard deviation above the mean, group creative processing had a statistically significant negative effect on group creative outcome ( $\beta = -8.67$ ,  $t = -2.44$ ,  $p < 0.06$ ; see figure 5). When conflict is one standard deviation below the mean, group creative processing had a statistically significant positive effect on group creative outcome ( $\beta = 6.69$ ,  $t = 3.75$ ,  $p < 0.05$ ; see figure 5). Thus, low conflict within groups benefits group creative outcomes and especially beneficial when group creative processing is high. In contrast, high levels of conflict within groups generally hurt group creative outcome especially when group creative processing is high.

## CHAPTER 4

### GENERAL DISCUSSION

In this dissertation, I conducted a field study of scientists in a nanobiotechnology research and development setting to investigate the link between the strength of ties and creativity. In studying the effect of dyadic relationships on individual creativity, I find tie strength to predict individual creative thinking. Mediation analysis suggests that competence-based trust and openly discussing ideas partly account for the observed relationship between strong ties and individual creative thinking. Additionally, openly discussing ideas had a larger positive impact on individual creative thinking when an individual interacts with a network tie that has the same functional expertise. Consequently, the greater number of strong ties an individual has, the higher his/her individual creativity as rated by the laboratory director and the other scientists. In studying the creativity of group projects, group tie strength density was found to predict group creative processing. Mediation analysis suggests that group-level trust and cooperation norms, but not psychological safety, partly accounts for the observed relationship between strong group tie density and group creative processing. Finally, conflict moderated the relationship between group creative processing and group creative work outcomes, such that group creative processing positively relates to group creative work outcomes when conflict is low. In contrast, group creative processing negatively relates to group creative work outcomes when conflict is high.

In general, the findings of this study suggest that strong ties present a relational advantage for creativity. In this chapter, I consider the theoretical and methodological implications of these finding. I then consider directions for future research. Finally, I conclude with a brief summary of the dissertation.



### ***Theoretical implications***

Classic work in social network theory postulates that weak ties contain more non-redundant information than strong ties (Granovetter, 1973; Marsden & Campbell, 1984). This is because strong ties tend to form between two people who are similar to each other, and they tend to have strong ties to the same set of people such that they are all mutually connected. In contrast, weak ties tend to form between two people who are dissimilar to each other, and weak ties tend to form a bridge between otherwise disconnected parts of the greater social system. Thus, the information received from strong ties is likely to be more redundant than information received from weak ties. Building off this classic work, networks researchers have so far postulated a link between weak ties and creativity (McFadyen & Canella, 2004; Perry-Smith, 2006; Perry-Smith & Shalley, 2003; Ruef, 2002). Yet, in the present study, strong ties more than weak ties were found to facilitate creativity. How might this difference be resolved? I offer three possible explanations.

### ***Weak and Strong Ties facilitate Different Kinds of Creative Thinking***

One possible explanation is that both weak ties and strong ties facilitate different kinds of creative thinking. Creative thinking is a process of combining or reconfiguring information to generate new ideas (e.g. Hargadon & Bechky, 2006). Creative thinking could therefore generally occur in two ways. Creative thinking might involve reconfiguring existing information in novel ways such that new ideas are generated. Alternatively, creative thinking might also involve searching for non-redundant information and combining non-redundant information with existing information to generate new ideas. Broadly then, there is two broad kinds of creative thinking: One that relies on accessing non-redundant information to introduce novelty into one's thinking and the other that relies on reconfiguring "old" information in

novel ways such that the new reconfiguration of existing information either represent new ideas or that new ideas are emerges from the new configuration. Both of which introduces novelty into an individual's thinking. Thus, it is possible that because weak ties contain more non-redundant information (or information that is more non-redundant) than strong ties, receiving information from weak ties should facilitate creative thinking more than strong ties. In this instance, weak ties facilitate creative thinking because these ties provide access to non-redundant information that can be combined with existing information to generate new ideas.

Alternatively, creative thinking does not necessarily vary with the amount of non-redundant information accessed nor does it necessarily vary with the extent of non-redundancy in information. Instead, creative thinking in this instance involves reconfiguring existing information. Because the reconfiguration of existing information to facilitate the generation of new ideas does not rely on non-redundant information, weak ties may be less beneficial for this kind of creative thinking. Reconfiguring existing information to generate new ideas typically involves breaking, changing, and/or reframing existing configurations of information such that new relationship can be discovered (e.g. Finke, Ward, & Smith, 1992; Wisniewski, 1997). In organizational contexts, the reconfiguration of information to think creatively often occurs through social interactions characterized by help seeking, help giving, reflective reframing and reinforcing (Hargadon & Bechky, 2006). That is, creative thinking based on reconfiguring existing information often involves repeated social interactions with a social exchange partner who is willing to expand the time and effort to this creative endeavor. Thus, in this instance, strong ties more than weak ties should facilitate creative thinking.

### ***Weak and Strong Ties facilitate Different Phases of Creative Thinking***

A second possibility is that both weak ties and strong ties facilitate different phases of creative thinking. As a process of combining information to generate new ideas, creativity involves both an information gathering phase and an information combination/implementation phase (e.g. Paulus & Yang, 2000; Taylor & Greve, 2005). The information gathering phase is important to creative thinking because it essentially defines the pool of ideas from which new ideas are generated. In some sense, there is a certain path dependency in creative thinking. The extent to which the final idea is novel and useful depends on the amount and variety of the initial pool of ideas. Thus, most research on creativity emphasizes the value of diversity and variation in the initial pool of ideas. With a greater variation in the initial pool of ideas, many different perspectives are considered which provides more opportunities for cross-pollination, all of which have been argued to facilitate creative thinking (e.g. Choi & Thompson, 2005; Kurtzberg & Amabile, 2001; Perry-Smith & Shalley, 2003). Since weak ties are more likely to provide access to non-redundant information than strong ties, having a greater number of weak ties should afford access to more diverse and varied pool of initial ideas. Thus, weak ties should facilitate creative thinking in that it contributes to the variation in the information gathering phase of creative thinking.

After the initial pool of ideas is constructed, the next phase in creative thinking is to either choose one of the ideas to implement or to combine some of the ideas to generate new composite ideas (Goncalo & Staw, 2006). Combining ideas to generate new composite ideas is not simple. Indeed, in many organizational contexts, idea combination often involves intense effort, sophisticated cognitive skills, and highly specialized experiences (Dunbar, 1997; Gentner & Markman, 1997; Taylor & Greve, 2006). For instance, in a study of molecular biologists at leading scientific laboratories

in the United States, Dunbar (1997) discovered that creative thinking involves continuously making incremental modifications to an idea and over time, this series of small modifications will eventually lead to major breakthroughs in scientific thinking. Alternatively, in a study of the comic book industry, Taylor and Greve (2006) find that comic book creators who have the most experience with different comic book genres are more creative than their lesser experienced counterparts because the more experienced creators are more effective at combining different ideas to generate new ideas. These examples suggest that not only does the idea combination phase of creative thinking involve effortful commitment to a course of work, it also facilitated by highly specialized knowledge and experience. This suggests that interacting with individuals who are both willing to share their highly specialized knowledge and experience and willing to exert a considerable effort in helping the recipient combine the newly received information facilitates the idea combination phases of creative thinking. Since strong ties are more like than weak ties to afford such help, it might be that strong ties facilitate the idea combination phase in creative thinking.

***Weak and Strong Ties facilitate Different Phases of Creative Thinking Differently:  
The Contingent Effect of Social Exchange Actor's Functional Expertise***

The third possibility is that depending on the functional expertise of the interacting actors, weak and strong ties facilitate different phases of creative thinking differently. This explanation is founded on this study's finding that openly discussing ideas had a greater positive impact on individual creative thinking when interacting with an individual who has the same functional expertise compared to when interacting with an individual who has a different functional expertise (see figure 4). I suggest that when individuals from the same functional area interact, weak ties facilitate the information gathering phase of creative thinking; whereas strong ties

facilitate the information combination phase of creative thinking. Conversely, when individuals from different functional areas interact, strong ties facilitate the information gathering phase of creative thinking; whereas weak ties facilitate the information combination phase of creative thinking (See figure 6).

<div> <div>Creative Phase</div> <div>Tie Strength</div> </div>	Information Gathering	Information Combination
	<b>Different Functional Area</b>	<b>Same Functional Area</b>
Weak Ties	<b>Same Functional Area</b>	<b>Different Functional Area</b>

***Figure 6: Contingent Effects of Functional Expertise on the link between Tie Strength and Creative Phase***

When gathering information from network ties in the same functional area, an individual is more likely to be able to access non-redundant information from weak ties since being from the same functional area, the social exchange actors already have overlapping knowledge and skills. Conversely, when gathering information from network ties in a different functional area, an individual is more likely to be able to access non-redundant information from strong ties since strong ties more than weak ties facilitate the transfer of highly specialized knowledge and skills that are often complex and tacit, i.e. hard to articulate (Hansen, 1999; Levin & Cross, 2004).

When combining information from network ties in the same functional area, an individual is more likely to combine non-redundant information from strong ties. Since being from the same functional area indicates overlapping expertise, both actors

are likely to be apprehensive about being revealing the gaps in their knowledge. Thus, when both actors are from the same functional area, strong ties are more likely to lead exchange actors to feel comfortable being open about gaps in their knowledge and also feel comfortable engaging in critical discussion about each others ideas, thereby facilitating creative thinking.

Conversely, when combining information from network ties from a different functional area, an individual is more likely to combine non-redundant information from weak ties. Since being from a different functional area indicates non-overlapping expertise, both actors are unlikely to feel any apprehension about revealing the gaps in their knowledge. Thus, when both actors are from different functional areas, weak ties are more likely to lead exchange actors to feel comfortable being open about gaps in their knowledge and also feel more comfortable engaging in critical discussion about each others ideas, thereby facilitating creative thinking.

### ***Methodological Implications***

Social networks researchers currently explain creativity in terms of whether network ties provide access to non-redundant information. They have so far relied on secondary data to draw inferences about the mechanisms underlying creativity through network ties, a limitation that is widely acknowledged (e.g. Fleming et al., 2007; McFadyen & Canella, 2004; Perry-Smith, 2006). For instance, McFadyen and Canella (2004) used archival data to infer how well two scientists knew each other by counting the number of times they published with each other. Based on this measure of network tie strength, McFadyen and Canella (2004) assert that even though each additional collaborator with diverse expertise benefits an individual's portfolio of creative work, there is a point where the additional cost of maintaining an additional collaborative relationship outweighs the creative benefits of adding that relationship.

Similarly, Uzzi and Spiro (2005) construct a network from archival data to find that increasing social cohesion in network structure enhances collaborative creativity but only to a point. Over time, because social cohesion facilitates information flow, cohesion in network structure results in the same information continuously cycling through the network such that what began as non-redundant information becomes homogeneous. Alternatively, Fleming et al. (2007) used archival data to show that, within a socially cohesive closed network of collaborations, working with collaborators who have broader creative experiences, work across multiple organizations, and have collaborators outside of the closed network, enhances creativity.

Even when primary data is collected, social network researchers infer hypothesized psychological mechanisms linking tie strength to creativity (e.g. Burt, 2004; Obstfeld, 2005; Perry-Smith, 2006; Rodan & Galunic, 2004). For instance, Perry-Smith (2006) theorized and concluded that weak ties (i.e. less close, shorter duration and lower communication frequency) are generally beneficial to creativity because weak ties should facilitate divergent, flexible, and autonomous thinking.

Similarly, Burt (2004) constructed network data by using network survey methods to measure if respondents discussed ideas with other colleagues. If respondents indicated they do, they were further asked to identify these colleagues and how often they discussed work issues with others in general. Based on these network measures, Burt (2004) concluded that an individual who has network ties that bridge two otherwise disconnected groups facilitates the individual's ability to effectively use information accessed from one group to introduce creative ideas to the other group.

This brief review illustrates the contemporary stance that whether creativity is enhanced or hindered depends on whether network ties provide access to non-redundant information. However, this review also reveals, to date, a mixed bag of

explanations for the mechanisms that mediate the link between tie strength and creativity. Thus, by empirically identifying competence-based trust and openness as mechanisms that mediate the link between strong ties and individual creative thinking, the present work highlights the importance of directly measuring hypothesized mechanisms when studying social network ties.

### ***Limitations and Directions for Future Research***

This study certainly has limitations and I focus my attention on three in particular: The problem of generalizing to larger organizations, the problem of neglecting work structure and in particular task interdependence, and the problem of causal direction linking tie strength to creativity.

The most salient limitation of the present study is the size of the network. At a network size of 30 people, I am cautious about generalizing the empirical findings and theoretical implications to large organizations where creativity is important, e.g. Google and General Electric. That being said, I believe the findings and implications of this study can be generalized to smaller organizations with 50 or less members, such as small to medium sized enterprises and small high-technology start-ups that are common place in Silicon Valley. Furthermore, studying an organizational network of a smaller size provides an important advantage in that it was possible to use refined measures to examine the complete network of relationships, or at least close to complete. Thus, the limitation of not generalizing to larger organizations trades off with the advantage of studying a complete network.

The second limitation of this study pertains to a lack of consideration of work structure, in particular task interdependence (Wageman, 1995). By definition, it seems reasonable to assume that interdisciplinary work is task interdependent. More importantly, task interdependence has a variety of implications for a study linking tie



strength to creativity. First, the extent of task interdependence between people working on the same project might account for a significant proportion of variance in tie strength. Since tie strength reflects interaction frequencies and how close two people work together, it almost seems obvious that task interdependence can directly affect tie strength. For instance, those working on highly task interdependent projects will spend a large portion of their time interacting with each other. Task interdependence can also influence creativity in that task interdependence might also affect the extent to which an individual's ideas are shaped by others' ideas. One might expect that the greater the task interdependence between two individuals, the more the ideas of one person will be listened to and combined with his/her own ideas. Alternatively, task interdependence could be the result of the link between tie strength and individual creativity. That is, task interdependence could be indicative of the strength of a group's work relationships. As the within group ties get stronger, individuals will spend increasing amounts of time working on a project such that in groups, such as self-organizing groups, might increasingly design their work around task interdependent work structures. For these briefly considered reasons, I suggest that future research might examine the interplay between tie strength, task interdependence, and creativity so as to gain some insight into the causal direction.

The third and perhaps most important limitation is the causal direction between tie strength and creativity. Does tie strength lead to creativity or does creativity lead to tie strength? While most social network research to date (e.g. Perry-Smith, 2006; Ruef, 2002), and the present study included, has assumed that tie strength leads to creativity; there is the alternative explanation that people tend to build stronger ties with those that they think are more creative. For instance, Perry-Smith & Shalley (2003) theorize that while creative individuals are mostly found in the peripheral positions of a network, these individuals' reputation for being creative will grow as more and more

people recognize the creativity of their work. Thus, as these individuals continue to produce creative work, more and more people will want to collaborate with them which results in the once peripheral creative individual moving towards more central positions in the network. Importantly however, as these individuals also begin to do less and less creative work because people will want to work with them on the very thing they became known for being creative in the first place. In other words, these individual's past successes as a creative individual increasing hurts their creativity as they become more central in the network (Audia and Goncalo, 2007).

Indeed, a recent work provides some empirical evidence showing that the most creative individuals in the Hollywood film industry tend to occupy (and maintain) intermediate positions within a network such that they may at the same time draw on the creative advantages of being in the core or peripheral position. Whereas the peripheral positions is associated with having access to non-redundant information and fresh information, the core positions can facilitate creativity in that the core positions provides access to relationships that aid the legitimatization of new ideas. Thus, this body of research raises the question of whether network position drives individual creativity or if individual creativity determines network position. It is quite likely that this link between network position and individual creativity is bidirectional in its influence. Since we know that peripheral creative individuals will become increasingly central in the network which in turn means that they risk becoming less creative, it raises the question of whether it is possible to find an optimal sweet spot in a network such that an individual or group can maximize his/her creativity.

### ***Direction One: Functional Diversity and Within-Group Tie Strength***

Is functional diversity necessary for groups to be creative? What about groups that have little or no functional diversity? Recent research suggests that group

creativity can be enhanced in functionally homogeneous groups through individualistic norms (Goncalo & Staw, 2006). In this instance, individualistic norms encourage group members to think independently which in turn facilitates divergent thinking in the group. If individualistic norms facilitate divergent thinking in groups, what is the link between within-group tie strength and group creativity?

According to Goncalo and Staw (2006), individualistic norms reflect a group situation where individual members are more aware of how they are different from how they are similar to each other. Given that within-group tie strength is indicative of interaction frequency and relationship closeness between members of a group, do stronger within-group ties enhance the salience of member differences or similarities? I argue that when groups are functionally homogeneous, strong within-group ties facilitates the development of individualistic norms. This is because people have a natural desire to be distinctive from others. Thus, when there is functional homogeneity in a group, I argue that the desire to be distinctive drives members to search for and pay more attention to how they might be intellectually distinctive from other members. Therefore, strong within-group ties in functionally homogenous groups should facilitate the development of individualistic norms, which in turn encourages divergent thinking, and thereby should facilitate group creativity.

Alternatively, when there is functional diversity in a group, I argue that there is less of a desire to be intellectually distinctive from other members. If anything, members of a functionally diverse group are likely to be more aware of other members' natural inclination to protect their respective intellectual turfs (Chubin, et al., 1984). Thus, when within-group ties in functionally diverse groups get stronger, groups should develop shared norms for encouraging moderate levels of task conflict accompanied with low relationship conflict (Jehn 1997; Jehn & Mannix, 2001). That is, strong within-group ties mitigate the likelihood that functional diverse groups

misinterpreting the emotional tension accompanying task conflict to be personal. This in turn should lead to divergent thinking, and thereby should facilitate group creativity.

Specifically, I propose that strong within-group ties enhance a group's effectiveness in managing the task and relationship conflict associated with divergent thinking in a group. This is especially true for functionally diverse groups. In contrast, I argue that when there is functional homogeneity in a group, the link between strong within-group ties and group creativity depends on the development of individualistic norms.

### ***Direction Two: Joint Effects of Within- and Between-Group Ties on Group Creativity***

The social network of a group comprises within-group and between group ties (Hansen, Mors, & Lovas, 2006; Oh, Chung, & Labianca, 2004; Oh, Labianca, & Chung, 2006). Although network ties in organizations can be very different, ranging from informal friendships to formalized business partnerships (Contractor, Wasserman, & Faust, 2006; Kilduff, Tsai, & Hanke, 2006), I focus my discussion only on those network ties that represent social relationships that provide access to information and ideas relevant to the group's work task (Balkundi & Harrison, 2005; Hansen, 1999; Hansen, et al. 2006; Reagans & Zuckerman, 2001; Reagans, Zuckerman, & McEvily, 2004). Thus, much like how studying both between-group and within-group ties in conjunction has revealed a more complete understanding of group performance such as productivity and knowledge sharing (Oh et al., 2004; Oh et al., 2006), such an approach should also inform a study of group creativity. For example, functional diversity was found to weaken a group's within-group ties to each other but strengthens a group's between-group ties to those who hold useful non-

redundant information (Reagans et al., 2004); both of which might have a similar positive impact on group creativity.

What might we learn about group creativity if we considered both within-group and between-group relationships together? I approach this question by considering how the strength of within-group and between-group ties might affect group creativity, where tie strength represents the relationship between two parties in terms of interaction frequency and friendship closeness (Granovetter, 1973; Hansen, 1999, 2002; Marsden & Campbell, 1984). I suggest that between-group tie strength affects the inflow of information and thereby shapes the pool of ideas and knowledge that groups work with. I further suggest that within-group tie strength influences whether groups effectively manage conflict such that members are effective in sharing and synergistically combining unique ideas. I then draw from research on trust and conflict to suggest that strong between-group and strong within-group ties facilitate group creativity.

### ***Between-Group Ties and Creativity***

Between-group ties represent the social relationships that serve as conduits of information inflow from other groups to the focal group. For instance, group members' communications with members of other groups accounts for the link between functional diversity and group creativity (Ancona & Caldwell, 1992a, 1992b; Reagans & Zuckerman, 2001). This is because with greater functional diversity in a group, the group communicates with other groups that provide access to a greater variety of functional knowledge. Thus, with greater functional diversity, a group should have access to a greater amount of non-redundant information when it communicates with other groups.

Similarly, at a structural level, social network theorists have demonstrated an inverted U-shape relationship between group creativity and the extent to which the network structure of groups' ties to each other resembles a small world (Fleming & Marx, 2006; Uzzi & Spiro, 2005). As groups form new ties to other groups, groups benefit from receiving non-redundant information from these new connections, but only to a point. When the social network structure begins to resemble a 'small-world' (Watts, 1999; 2004), i.e. when the number of between-group connections in the network is very high and dense, the information flowing between groups tend to be redundant. Together, these studies suggest that the more between-group ties provide access to non-redundant information, the greater group creativity.

Further, to avoid over-complicating the analysis, I assume that only one tie exists between any two groups. Each group member's tie to another person in another group is unique to that dyadic relationship and functions as the only bridge by which information flows between the two groups. With this assumption, I suggest that group members' perception and understanding of the information received from another group depends on that one specific group member who has a tie to the particular group. Information from another group is accessed by that one specific group member who then proceeds to evaluate and combine the received information with his/her own held information to generate the unique idea(s) that he/she would share with the rest of the group members. Thus, the form by which a group perceives and understands information received from another group depends entirely on the interpretation and presentation of the individual member who has a tie to the other group. As a result, the information received from other groups that begins circulating within a group may or may not resemble its original form. Rather, information received from other groups begins circulating in the form by which the information was first presented to the group as individual members' unique ideas. Therefore, between-group ties affect

group creativity in that these ties directly affect the form of the pool of ideas and information that the group works with.

Indeed, group creativity involves members expending significant effort to think of novel and useful ways to combine non-redundant information accessed from other group with their own information (Amabile, 1988; Drazin, Glynn, & Kazanjian, 1999; Nonaka, 1994; Woodman et al., 1993). Specifically, group creativity is a process that involves individual members accessing useful non-redundant information from between-group ties, effortfully processing of the non-redundant information to glean new insights, and subsequently combining the newly received information with their own information to generate unique ideas from which the group generates creative outcomes.

### ***Within-Group Ties and Group Creativity***

I assume that within a group, all members can form a tie to each other. With this assumption, I suggest that within-group ties directly affect group members' perception and understanding of each other's ideas. That is, within-group ties influence how groups evaluate and combine the ideas exchanged between group members to generate novel and useful group outcomes (Amabile, 1996; Taylor & Greve, 2006; Woodman, Sawyer, & Griffin, 1993). Thus, I suggest that between-group and within-group ties affect different phases of group creativity. Between-group ties affect the flow of information into a group by how individual group members combine information accessed from other groups with their own information and introduced to the group as unique ideas. These ideas are then evaluated and combined through within-group ties to generate creative outcomes.

With this two-phase model in mind, I suggest that a combination of strong within-group ties and strong between-group ties facilitate creativity in groups.

Specifically, competence-based and benevolence-based trust accounts for individual members receiving useful non-redundant information from other groups. The received non-redundant information shapes the generation of unique ideas, which the recipient shares with the other members in the group. Once these ideas are shared with the group, conflict norms and working atmosphere determine whether divergent thinking occurs within a group, and subsequently affecting the group's creativity.

### ***Direction Three: Status Competitions and Group Creativity***

In this chapter, I suggest that the creativity of groups embedded in social networks occurs in two parts. Non-redundant information is gathered from between-group ties. The non-redundant information received from these between-group ties shapes the unique ideas each individual member brings to the group. These unique ideas that individual members contribute forms the pool of ideas the group will draw on. Within-group tie strength then determines whether divergent thinking occurs in the group and subsequently affects group creativity. However, I have so far assumed that a group's within-group and between-group ties have separate and independent effects on group creativity.

For instance, brainstorming research suggests that ideas enjoy more influence when shared by group members who have a reputation for having good ideas (Sutton & Hargadon, 1996). However, while the reputation for good ideas can be developed through "winning status competitions" within a group (Sutton & Hargadon, 1996), status competitions can lead to ideas originating from within the group to be perceived as more threatening than ideas originating from outside the group (Menon, Thompson, & Choi, 2006). Ideas are influential only when these ideas do not represent a status threat in the form of relegating the other group members to a "follower" role (Menon, et al., 2006). Alternatively, when ideas originating from within do represent a threat,



ideas originating from between-group ties will have more of an influence in shaping the group's outcomes.

However, whether ideas originating from between-group ties will have more of an influence on the group's creativity is not simply a by-product of within-group status competitions conferring goodness on ideas originating from between-group ties. Instead, ideas originating from between-group ties must present the group with a fresh perspective (Guimera et al., 2005; Uzzi & Spiro, 2005). Further, ideas originating from between-group ties have little influence on the group's creativity if the usefulness of these ideas is difficult to verify and too difficult to integrate with ideas originating from within (Ancona & Caldwell, 1992a). Thus, ideas originating from between-group ties should enhance group creativity only when these ties provide access to ideas that are both good and different from ideas originating from within.

This suggests a joint effect of within-group status competitions and between-group ties on group creativity. On the one hand, within-group status competitions affect whether ideas originating from within are preferred over ideas originating from between-group ties. On the other hand, whether ideas originating from between-group ties have an influence depends on whether these ideas bring a different and useful perspective. Group creativity, therefore, might depend on the joint effects of within-group status competitions and between-group ties increasing both the size and diversity of the pool of ideas that can have an influence on the group's final idea, solution, or product

## ***Conclusion***

In this dissertation, I suggest that strong ties facilitate creativity. Results from a field study of biotechnology scientist shows that competence-based trust and openly discussing ideas accounts for the link between strong ties and individual creative thinking. Additionally, openly discussing ideas had a greater effect when there is social interaction between two individuals from the same functional area. This study also shows that group-level trust and cooperative norms partly account for the link between strong group ties and group creative processing. In turn, group creative processing leads to group creative work outcomes when conflict is low. In closing, this study presents evidence that strong ties provide a relational advantage in facilitating creativity.

## APPENDIX A

### **Phase 2 Survey Instructions:**

The table on the next page contains the names of the members of Laboratory Name. Read each of the following statements carefully. For each person in the table, indicate your response to the set of questions below. Select the appropriate rating from 1 to 7 as in the scale below and write it in the corresponding cell in the table. (1 = not at all; 2 = very little; 3 = somewhat little; 4 = neither; 5 = somewhat much; 6 = very much; 7 = a great deal).

- Tie Strength:** (1) How frequently do you have work-related interactions with this person?  
(2) To what extent do you consider this person a close friend?  
(3) How frequently does this person have work-related interactions with this you?  
(4) To what extent does this person consider you a close friend?

- Competence-based trust:** (1) How often do you seek work-related advice from this person because this person is an expert in his/her research area?  
(2) How much do you trust this person's intellectual abilities?

- Openly discussing ideas:** (1) How comfortable are you openly discussing your ideas with this person?  
(2) How comfortable are you critically discussing this person's ideas?

## APPENDIX B

### **Phase 3 Survey Instructions:**

Please rate on a scale of 1 to 7 how representative the following statements are when you and your collaborators are working on this project.

- Group-Level Trust:**
- (1) To what extent are members certain that you can fully trust each other when working on this project?
  - (2) To what extent are members always truthful and honest with each other when working on this project?
  - (3) To what extent do members absolutely respect each other's competence?
  - (4) To what extent can members trust each other's intellectual abilities when working on this project?
  - (5) To what extent can members trust each other to produce quality work when working on this project?
  - (6) To what extent can members freely share ideas with each other without fear of being wrong?
  - (7) To what extent do members feel that they can freely critique each other's ideas when working on this project?
  - (8) To what extent do members seek help from each other when faced with difficulties at work?

- Cooperative Norms:**
- (1) There is little collaboration among project members.
  - (2) There is a high level of cooperation among project members.
  - (3) There is sharing of knowledge between members.
  - (4) Members openly exchange ideas.

- Psychological Safety:**
- (1) If you make a mistake, how often do the rest of the members hold it against you?
  - (2) To what extent are members able to bring up problems and tough issues?
  - (3) To what extent do members reject others for being different?
  - (4) To what extent is it safe to take a risk in this group?
  - (5) To what extent is it difficult to ask other members for help?
  - (6) To what extent would members deliberately act in a way that undermines your efforts?
  - (7) To what extent are your skills and abilities valued and utilized on this project?

**(Appendix B continues on the next page)**

## APPENDIX B (continued)

- Conflict:** (1) How much personal friction is there amongst members when working on this project?
- (2) How much were personality clashes evident amongst when working on this project?
- (3) How often do members get annoyed with each other when working on this project?
- (4) How much tension was there amongst members when working on this project?
- (5) How much emotional conflict is there amongst members when working on this project?
- (6) How frequently were there conflicts about ideas amongst members when working on this project?
- (7) How much conflict was there about work being done amongst members when working on this project?
- (8) How frequently do members have disagreements about the task when working on the project?
- (9) To what extent were there differences of opinions amongst members when working on the project?

## APPENDIX C

### **Phase 4 Survey Instructions:**

Describe the work-related interactions between you and your colleagues at the Laboratory Name.

The table on the next page contains the names of the members of Laboratory Name.

Read each of the following statements carefully. For each person, indicate your response to the set of questions below. Select the appropriate rating from 1 to 7 as in the scale below and write it in the corresponding cell in the table. (1 = not at all; 2 = very little; 3 = somewhat little; 4 = neither; 5 = somewhat much; 6 = very much; 7 = a great deal).

### **Individual Creative Thinking:**

- (1) To what extent does this person share information you do not already know?
- (2) To what extent does this person share practical know-how (e.g. tricks of the trade) that he/she learned through his/her own experience?
- (3) How much effort do you put into thinking about information shared by this person?
- (4) How much do you continue to ponder information shared by this person after you interacted with this person?
- (5) How often does the information shared by this person challenge your ideas?
- (6) How often do you learn something new from information shared by this person?
- (7) How rarely do you gain new insights from information shared by this person? (reverse coded)
- (8) To what extent do you combine information shared by this person's with your own information to generate new ideas?

## APPENDIX D

### **Phase 5 instructions for peer ratings of individual creativity:**

The table on the next page contains the names of the members of Laboratory Name. Read each of the following statements carefully. For each person (including yourself) in the table, indicate your response to the set of questions below. Select the appropriate rating from 1 to 7 as in the scale below and write it in the corresponding cell in the table. If you are not sure of the appropriate response, use your best judgment. All responses will be kept confidential.

#### **Peer rated**

- individual creativity:** (1) To what extent do you consider this person an expert in his/her research area?
- (2) To what extent does this person generate original ideas compared to others in the lab?
- (3) How often do this person's original ideas lead to good solutions?
- (4) How often does this person stimulate creative thinking in others?
- (5) How often does this person produce creative work?

### **Phase 5 instructions for supervisor ratings of individual creativity:**

The table on the next page contains the names of the members of Laboratory Name. Read each of the following statements carefully. For each person in the table, indicate your response to the set of questions below. Select the appropriate rating from 1 to 7 as in the scale below and write it in the corresponding cell in the table. If you are not sure of the appropriate response, use your best judgment. All responses will be kept confidential.

#### **Supervisor rated**

- individual creativity:** (1) To what extent do you consider this person an expert in his/her research area?
- (2) To what extent does this person generate original ideas compared to others in the lab?
- (3) How often do this person's original ideas lead to good solutions?
- (4) How often does this person stimulate creative thinking in others?
- (5) How often does this person produce creative work?

## APPENDIX E

### **Phase 5 instructions for supervisor ratings of group creative outcome:**

The following statements represent your judgment of the project. Please read each statement carefully and indicate how accurately each particular statement represents your perspective.

- Group Creative Outcome:**
- (1) This project has the potential to generate novel solutions.
  - (2) This project has the potential to generate interesting solutions.
  - (3) Overall, this is a very original project.
  - (4) This project uses new techniques to solve existing problems more effectively than existing techniques.
  - (5) This project addresses an important biological question.
  - (6) Overall, the project will make a valuable contribution to biology.



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